Final Report

Regional Ecological Resource Assessment of the Rio Grande Riparian Corridor: A Multidisciplinary Approach to Understanding Anthropogenic Effects on Riparian Communities in Semiarid Environments

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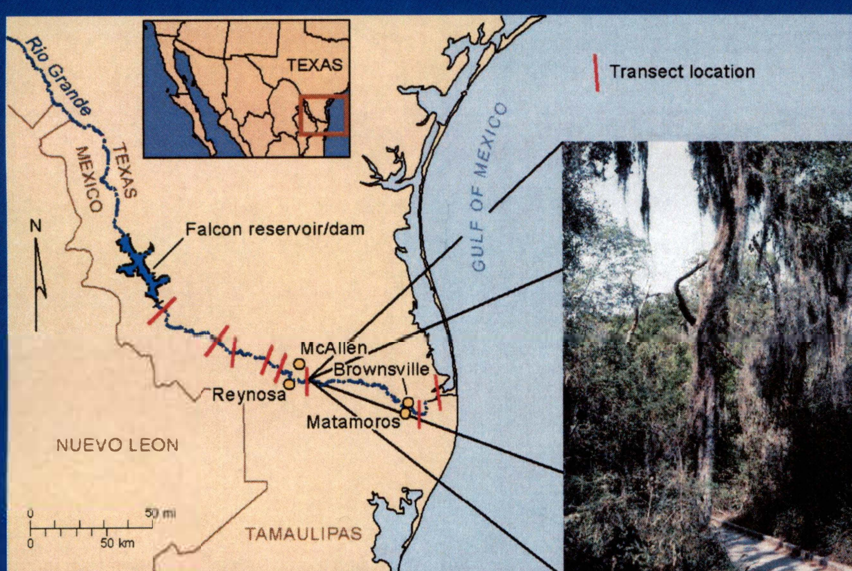

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EXECUTIVE SUMMARY

Riparian ecosystems of the southwestern United States are among the most productive ecosystems of North America. The rapid decline of these ecosystems throughout the United States, including the Lower Rio Grande Valley, has made riparian conservation a focal issue. This multidisciplinary study of riparian communities along the Lower Rio Grande of Texas and Mexico had several objectives, including (1) acquiring and analyzing high-resolution, remotely sensed data from multiple sensors; (2) integrating existing and new field data and remotely sensed data into a geographic information system (GIS); (3) ascertaining whether the native vegetation communities are maintaining themselves and identifying the topographic, edaphic, and other ecological factors that perpetuate these communities; (4) interpreting spatial variations in riparian habitats, including comparisons of the north and south banks of the Rio Grande; (5) analyzing temporal changes at specific locations; and (6) developing a foundation for future analysis of riparian floodplain communities by linking local and remotely sensed regional data using GIS.

Analysis and classification of riparian vegetation in the Lower Rio Grande Valley using remote sensing data supported by field surveys confirmed what other researchers have qualitatively suggested, that riparian vegetation has been greatly diminished since the early 1900's. Digital analysis of historical maps and aerial photographs of woodland distribution in Cameron County as part of this study revealed that in the mid-1930's there were ~ 81,887 ha of woodlands in Cameron County. By the early to mid-1980's, only 7,337 ha of woodlands in this original area

remained, indicating a loss of ~ 91% of this resource. This quantitative assessment of woodland loss helps confirm the earlier qualitative estimates of up to 95 % loss.

Although, today, riparian vegetation in the Lower Rio Grande Valley has a limited distribution, reseachers at UT-PanAm, based on repeated vegetation surveys, concluded that the dominant trees and shrubs along the Rio Grande appeared to be replacing themselves. In addition, they found that there were no trees at the mouth of the river and the vegetation there was similar to that found along the Laguna Madre shore of barrier islands. Mesquite (*Prosopis glandulosa*) was the dominant tree near the coast, where soil salinity and wind-blown salt spray are greatest, and it was also dominant in the western section of the river near Falcon Dam, where rainfall is least and where the Rio Grande floodplain is narrow. Sugar hackberry (*Celtis laevigata*) was the dominant tree species at all other sites except at Santa Ana National Wildlife Refuge, where cedar elm (*Ulmus crassifolia*) and anacua (*Ehretia anaqua*) were the dominant trees. Granjeno (*Celtis pallida*) was a dominant shrub throughout the riparian corridor. The introduced Guinea grass (*Panicum maximum*) and buffel grass (*Pennisetum ciliare*) were the dominant species in the ground cover, displacing native species. The present riparian communities may be greatly influenced by human interventions such as construction of dams that have eliminated annual flooding of the Rio Grande. Blair (1950) reported that cedar elm (*Ulmus crassifolia*) was the dominant tree in the floodplain of the Rio Grande in the Lower Rio Grande Valley of Texas. We found cedar elm was a dominant species only at Santa Ana NWR (Lonard and Judd, 2002). This species' distribution and abundance may have been adversely affected by the curtailment of annual flooding of the Rio Grande. Certainly, it is no longer a widespread dominant species in the riparian zone of the lower reach of the Rio Grande.

Using remote sensing data acquired of the Lower Rio Grande Valley, scientists at the Center for Space Research (CSR) analyzed and classified woodlands and riparian vegetation. The most recent Landsat imagery acquired between 2000 and 2002 was used to determine the current distribution of riparian woodlands. The data set was entered into the Bureau of Economic Geology (BEG) GIS for analysis. In addition to the lower-resolution multispectral (Landsat TM) data analyzed by CSR, high-resolution hyperspectral (HYMAP) data was acquired of selected sites and used to refine our classification of woodlands and riparian vegetation. CIR photography with 1-m resolution, in conjunction with the high-resolution (4 to 7 m) spectrally calibrated hyperspectral data supported by field surveys were used to train classification algorithms and visually evaluate resulting classes in the Santa Ana National Wildlife Refuge and Bentsen-Rio Grande Valley State Park. The Santa Ana National Wildlife Refuge contains one of the largest contiguous riparian communities along the Rio Grande. The remote-sensing signatures at training sites on the high-resolution data were used for classification of medium-resolution Landsat 7 data in order for us to evaluate the utility of these sites in (1) scaling upward from medium to high resolution data and (2) improving the riparian classification of the medium resolution data. The Landsat 7 data have extensive areal coverage but lower spatial and spectral resolution than that of hyperspectral data and lower spatial resolution than that of DOQ's.

Because of the large number of species representing riparian vegetation along the Rio Grande and the difficulty in adequately differentiating the various species using remotely sensed imagery, we established five classes of vegetation communities defined by the presence of evergreen and deciduous species and combinations of the two. The composition of the vegetation was determined from field surveys and interpretation of high-resolution, digital CIR aerial photographs (DOQ's) acquired during winter months. This classification approach is modeled after the USFWS National Wetlands Inventory program, in which riparian vegetation inventory and mapping conventions were developed for the Western United States. The USFWS classification is hierarchical, with the Riparian System having two subsystems, lentic and lotic, subdivided into forested and scrub/shrub classes. These, in turn, have three subclasses—deciduous, evergreen, and mixed, from which we established five subclasses consisting of (1) evergreen; (2) deciduous; (3) mixed, co-dominant; (4) mixed, evergreen dominant; and (5) mixed, deciduous dominant. Examples of common evergreen species identified through field surveys in the Santa Ana National Wildlife Refuge and along other reaches of the Rio Grande include Texas ebony (*Chloroleucon ebano*), anacua (*Ehretia anacua*), granjeno (*Celtis pallida*), la coma (*Sideroxylon celastrina*), huisache (*Acacia minuata,* and tepeguaje (*Leucaena pulverulenta*). Examples of deciduous species include hackberry (*Celtis laevigata*), cedar elm (*Ulmus crassifolia*), mesquite (*Prosopis glandulosa*), black willow (*Salix nigra*), retama (*Parkinsonia aculeata*), Texas persimmon (*Diospyros texana*), and Rio Grande ash (*Fraxinus berlandieriana*). This last species is deciduous, or semi-evergreen.

Using remote sensing data of various scales, resolution, and seasons of acquisition, and supported by the detailed field surveys, we classified riparian vegetation communities into the five classes defined by the presence of evergreen and deciduous species and combinations of the two as described above. We achieved relatively good results in the Santa Ana NWR (Fig. 2), however, poorer results were achieved in scaling upward from the hyperspectral data to Landsat 7 TM data; results degraded further when extended beyond the refuge. Although general trends in vegetation communities outside the refuge were defined, boundaries between classes were less distinct and there was a larger scattering of classes. We concluded that the best results in the evergreen and deciduous characterization were obtained using only three subclasses -- evergreen, deciduous, and mixed -- as defined by the USFWS. Five subclasses, as discussed above, could not be as consistently classified because of complex mixtures in vegetation communities.

Digital land-use and climate maps were completed by The University of Texas at Brownsville (UTB). Current land use was based on maps prepared from 1995 DOQ's and historical land use was based on existing BEG land use maps based on 1960 aerial photographs. The largest land-use parcel was agriculture followed by range-pasture and urban. Observations from the Brownville-Harlingen-McAllen sector of the LRGV show that the urban-residential category increased dramatically from 1960 to 1995. There was a slight decrease in agricultural land use. Overlays of 1995 and 1960 data show an explosive growth of residential urban parcels, particularly in the McAllen-Pharr-Edinburg area. Mapping of woodland shows very little of this category left in Hidalgo County. The year 2000 United States Census data for the four counties of the Lower Rio Grande Valley of Texas show a combined population approaching 1,000,000. The land use maps graphically indicate how this growth has impacted natural vegetation.

Maps on climate include average annual precipitation, September precipitation, average annual temperature, January mean temperature, July mean temperature, heating degree days, and cooling degree days. The climatic maps show systematic variations in precipitation and temperature in the study area, including decreasing average rainfall and increasing average temperatures as one proceeds up the Rio Grande Valley from the Gulf of Mexico. There is evidence that the decreasing annual precipitation up the Valley corresponds with a relatively lush mesic plant community in riparian areas near the coast to a more xeric assemblage farther inland.

There is a strong correlation between riparian vegetation and soils. Along the Rio Grande in Cameron County, for instance, although 17 different soils were associated with riparian vegetation, 3 soils made up more than 60% of the association (Rio Grande silt loam—22%; Zalla loamy fine sand—21%, and Matamoros silty clay—18%). Within a 3-km-wide corridor along the Rio Grande, which includes Cameron, Hidalgo, and Starr Counties, we found a similarly strong relationship. Within the 3-km corridor, these three soils plus Laredo silty clay loam cover only 32% of the area, but they are the soils on which 61% of the riparian vegetation occurs.

To further investigate the relationship between soils and riparian vegetation, we analyzed the distribution of common species of trees and shrubs that were identified at the ~160 field sites visited by researchers from UT-PanAm. All shrub and tree species identified at the sites were entered into our GIS, and a GIS layer of the common species found at the sites was developed for analysis of soil relationships. Results indicate that most species were more common on two soils, Laredo Silty Clay Loam and the Rio Grande Silt Loam. There were fewer occurrences on clays such as the Grulla Clay and Harlingen Clay. In addition, we analyzed the relationship between soil salinities and 10 common species of shrubs and trees. This was accomplished by analyzing the number of occurrences of the trees and shrubs on soils with salinities (based on conductivity) ranging from 0 to 4 millimhos/cm. This analysis was based on all species found at distinct field check sites and transect locations, as reported by Lonard and Judd, 2002. Soil salinity is represented as electrical conductivity in millimhos per centimeter at 25° C. The Natural Resource Conservation Service classifies soils as either nonsaline (0–2) or slightly saline (2–4). Among the results was that *Prosopis glandulosa* (mesquite) occurred more frequently in slightly saline soils than did other species. This finding is in agreement with that of Lonard and Judd (2002), who found mesquite to be the dominant species near the coast, where the effects of salinity and salt spray are most pronounced. This relationship between vegetation and soils, when correlated with other parameters such as topography, hydrology, and land use, is useful in analyzing riparian vegetation with respect to historical trends, anthropogenic effects, and optimal sites for reestablishment of riparian tracts.

To make comparisons between the remaining riparian vegetation in Texas and Mexico, we created a 20-km-wide buffer zone along the Rio Grande, with 10 km on the U.S. side and 10 km on the Mexico side (Fig. A). By comparing the distribution and amount of riparian vegetation classified within the 20 km corridor along the Rio Grande (10 km in the U.S. and 10 in Mexico), we found that of the total woodlands mapped within this area of analysis, 74 % occurs in the U. S., and 26 % occurs in Mexico. However, compared to other types of land cover such as cropland, only small percentages of woodlands, 6 % in the U.S. and 2 % in Mexico, remain. If we assume that in the past, most of the area was vegetated with riparian woodlands and brushlands as has been suggested by some authors, then almost 95 % of these wooded areas have been cleared in the U.S., and 98 % in Mexico. On the U.S. side, this is in agreement with estimates by Jahrsdoerfer and Leslie (1988) who stated that since the early 1900's, 95 % of the native brushland has been cleared for agriculture, urban development, and recreation, and in riparian areas they estimated that 99 % of native brush has been destroyed.

Among the more optimistic aspects regarding riparian vegetation along the Lower Rio Grande Valley are the efforts of the U.S. Fish and Wildlife Service, the Texas Parks and Wildlife Department, and National Audubon Society. These agencies have been involved in programs that actively help preserve and restore riparian habitats ranging from the TPWD's acquisition of white-winged dove habitat, to the National Audubon Society's Sabal Palms Santuary, and the USFWS large-scale acquisitions as part of the USFWS LRGV National Wildlife Refuge.

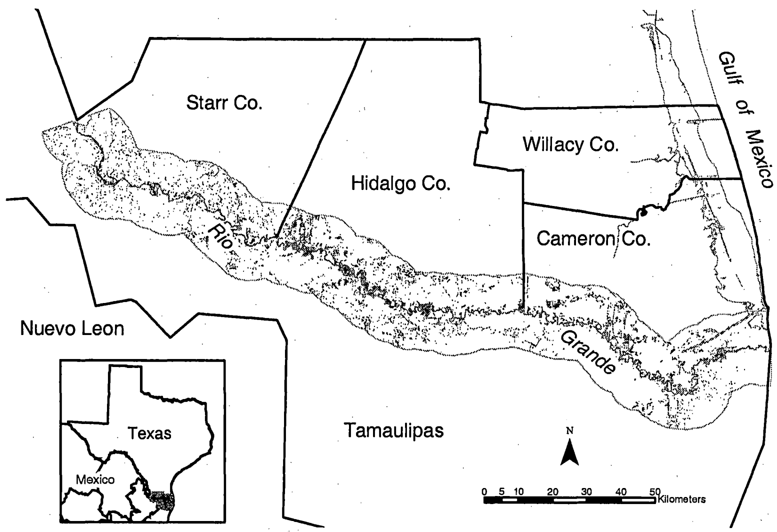

Figure A. Illustration showing 20-km buffer zone along the Rio Grande from the Gulf of Mexico to Falcon Dam, within which analysis of riparian vegetation was analyzed in the U.S. and Mexico. Dark (red) areas are riparian woodlands.

Associated with the acquisition of land is a rigorous planting program in which a variety of evergreen and deciduous shrubs and trees are being planted to help restore riparian habitat corridors along the Rio Grande. It is hoped that the analysis of riparian distribution and dominant plant species identified and reported in this study and their relationship to soils, hydrology, land use, salinity, topography, and other parameters will assist in riparian restoration programs in the Lower Rio Grande Valley, and serve as a foundation for future analysis of riparian floodplain communities by linking local and remotely sensed regional data using GIS.

INRODUCTION

Riparian ecosystems of the southwestern U.S.A. are among the most productive ecosystems of North America (Briggs, 1996), and they are characterized by high species diversity in both plants and animals. The mesic conditions prevailing in riparian communities permit the establishment and growth of many plant species, especially trees, which are not found on the adjacent more xeric uplands. Riparian ecosystems in arid and semiarid parts of the world differ in many ways from those in humid climates, but one of the most striking is the marked transition from the more abundant surrounding xeric-adapted communities to the mesic riparian zone. Indeed, in many places it is literally possible to take one step and pass from a xeric community to a mesic community. Usually, riparian communities in arid and semiarid lands exist as relatively narrow mesic corridors in a sea of xeric communities. Despite their relatively small areal extent, riparian corridors are crucial to the existence of a number of wildlife species, several of which are endangered, such as the ocelot (*Leopardus pardalis*), and jaguarundi (*Felis yagouarundi*) (Jahrsdoerfer and Leslie, 1988). Riparian ecosystems are declining throughout the southwestern U.S.A. and many have disappeared completely (Briggs, 1996). The rapid decline of these valuable ecosystems has made riparian conservation a focal issue for the public, federal, and state governments, and private organizations. For example, riparian forest along the Rio Grande in the Lower Rio Grande Valley of Texas has been identified by the U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department as an area where wildlife habitat is rapidly vanishing and in dire need of protection. To preserve and to re-establish the riparian forest and to establish a "wildlife corridor" along the Rio Grande, the U.S.A. and Texas governments are purchasing lands along the river to form a continuous riparian corridor along the Rio Grande from Falcon Dam on the west to the mouth of the river at Boca Chica on the east (Jahrsdoefer and Leslie, 1988).

A riparian corridor is a band of vegetation along a river that differs from the surrounding vegetation. Although riparian corridors are well-defined landscape features, they are not closed autonomous systems. Continuous interactions occur between aquatic, riparian and upland ecosystems through exchanges of energy, nutrients, and species. In addition, lands adjacent to rivers are connected to upstream and downstream ecosystems. Thus, riparian corridor dimensions are based more on function than on specific boundaries where adjacent vegetative communities interface. The ability of a riparian corridor to filter surface runoff, contribute nutrients to instream organisms, and furnish feeding and nesting sites to terrestrial wildlife is often directly related to the width of the corridor. Clearly, to accomplish these functions a riparian corridor should be wide enough to cover the flood plain, both banks of the river and a band of uplands (at least on one side of the river). Formulae for determining corridor widths necessary to maintain water quality and quantity have been developed, but information for determining corridor dimensions necessary for providing required wildlife habitats have not been published.

Unlike plants, animals do not occur in the same distinct zonal pattern from aquatic to upland areas. Many wildlife species contribute to the ecological function of riparian communities, but few species are restricted to them. The use of riparian corridors by wild life differs by species, season, and flooding regime. For example, many terrestrial birds nest close to rivers and forage over large areas including both riparian and upland communities. Maintenance of the integrity of riparian corridors requires strategies that address hydrological cycles, instream flow regimes, and the quality and quantity of communities within the corridor.

This project, designed to increase our understanding of riparian communities along the Rio Grande, was a multidisciplinary, multi-university cooperative study. Entities included the Bureau of Economic Geology at the University of Texas at Austin (UTA-Bureau), the Center for Space Research at the University of Texas at Austin (UTA-CSR), the Earth Science and Biology Departments at the University of Texas at Brownsville (UTB), and the Biology Department at the University of Texas-Pan American (UTPA). Each school made technical contributions in their specific areas of expertise. For example, researchers at UTB, which is located in the study area, had knowledge of land use and were experienced in digitizing maps using ESRI software; UTB researchers interpreted and digitized current land use of much of the study area. Researchers at UTPA have years of experience in botanical studies of the Lower Rio Grande Valley (LRGV), and during this project conducted detailed, sub-meter scale vegetation transects along the Rio Grande at 11 sites, and provided ground truth on vegetation composition at approximately 160 additional sites. UTA-CSR has an international reputation for development of algorithms and analysis of remotely sensed data. CSR researchers acquired and analyzed data from numerous multiresolution and multisensor images of the study area to define the extent and distribution of riparian vegetation. The Bureau managed the project, relying on its extensive experience in managing large cooperative projects, and in relating remotely sensed data with biological and physical data using GIS-based technology.

STUDY AREA

The study area is located on the Rio Grande from Falcon Dam, Starr County, to the mouth of the river in Cameron County, a distance of about 240 km (Figs. 1 and 2). The lower course of the Rio Grande, which has constructed the delta in Cameron County, is a region with subtle environmental differences in geology, climate, soils, and natural vegetation when compared with the reaches of the river further inland. Cameron County is in the distributary system for the Rio Grande. Here, bedrock features are absent and the river, until human intervention, meandered freely. Numerous ox-bow lakes, locally known as resacas, are present. Sediment size is much finer than areas further inland, ranging between fine silt and clay. Drainage is a problem after heavy storms; ponding of water is now quite prevalent in urban areas. Most of the natural vegetation of Cameron County has been disturbed. Urbanization and agricultural land use have greatly altered the landscape, and many of the plant species present are now invasive or imported. Several local sites, however, reflect an almost undisturbed natural environment including Sabal Palm Grove Sanctuary east of Brownsville. Emphasis for GIS overlay analyses to determine the relationship between various parameters was placed on corridors along the Rio Grande ranging in width from the river's edge to distances of 3 km and 10 km (Fig.

1) on each side of the river. Field studies of vegetation were concentrated primarily along transects located on the river's edge, and at over 160 specified sites away from the river on the U.S. side of the Rio Grande.

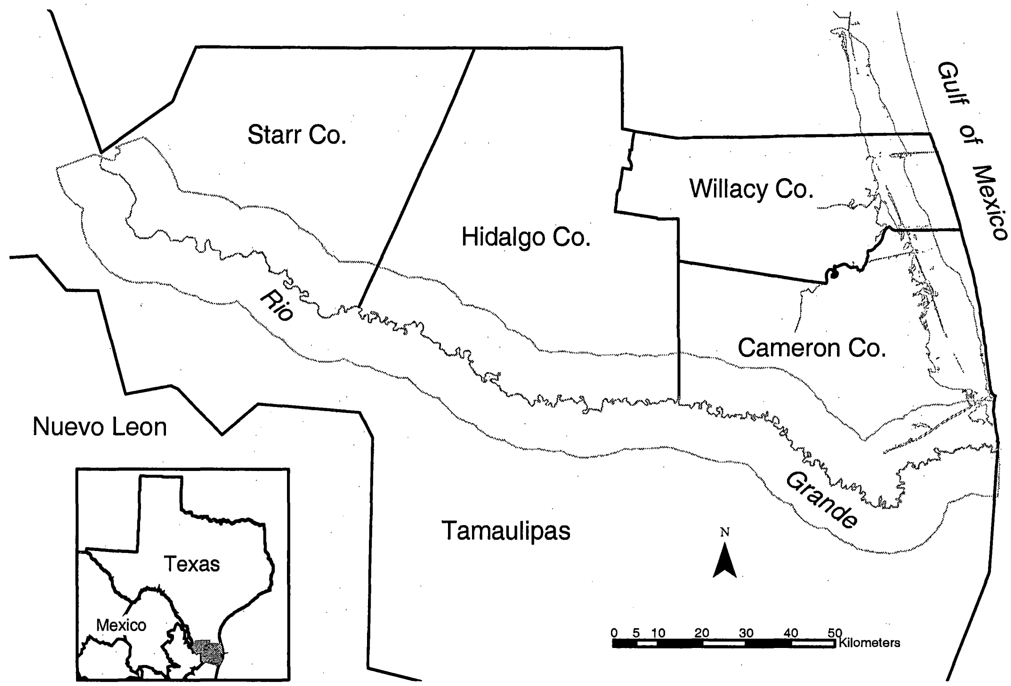

Figure 1. Location map of Lower Rio Grande Valley showing U.S. counties and Mexico states and a 20 km wide corridor along the Rio Grande along which riparian vegetation distribution was analyzed.

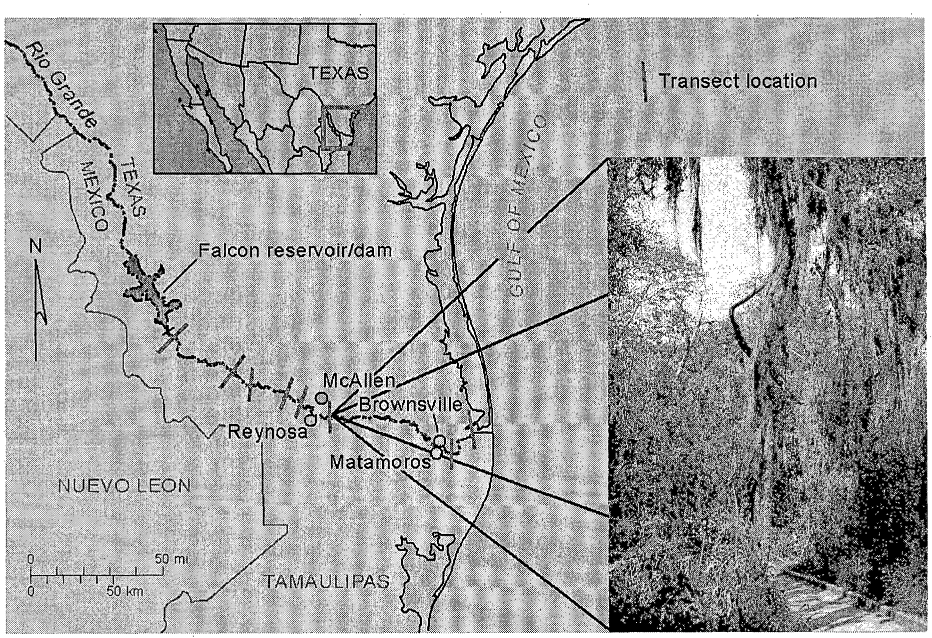

Figure 2. Index map showing the Rio Grande and approximate locations of eight of eleven vegetation transects along the river. Photo of riparian vegetation was taken in San Anta National Wildlife Refuge.

OBJECTIVES

Among the objectives of this project were to (1) acquire and analyze high-resolution remotely sensed data from multiple sensors, including airborne hyperspectral systems, synthetic aperture radar, laser altimetry, and videography, medium-resolution remotely sensed data from Landsat and SPOT within the Lower Rio Grande Valley riparian corridor, (2) integrate existing and new field data and remotely sensed data into a GIS to map the riparian vegetation of the lower reach of the Rio Grande, (3) ascertain whether the native communities are maintaining themselves, (4) identify the topographic, edaphic, and other ecological factors that perpetuate these communities, (5) interpret spatial variations in riparian habitats, including comparisons of the northern and southern banks of the Rio Grande, (6) analyze temporal changes at specific locations, and (7) develop a foundation for future analysis of riparian floodplain communities by linking local and remotely sensed regional data using a GIS.

Our objectives and methods were designed to help answer questions such as: What is the anthropogenic impact on the riparian areas in the region? How extensive is the riparian habitat? How can we assess and manage changes in the resource cost-effectively? How representative are the in-place field ecological data over the region, and how do they correlate to remotely sensed data? What types and resolutions of remotely sensed data are most useful? How do the hydrology, soils, and water quality in the region affect the ecology?

METHODS

Data Acquisition, Analysis, and GIS Development

Existing and new detailed local-scale (0.5-1 m) ecological field data in the form of vegetation transect statistics and species composition at selected sites were correlated with existing and newly acquired high-resolution (4-7 m) hyperspectral data and high-resolution digital CIR aerial photographs to delineate and classify riparian vegetation. This provided ground truth for the classification output. Classification output from high-resolution imagery provided the class mixtures for medium-resolution (20-30 m) Landsat Enhanced Thematic Mapper (ETM+) multispectral data that cover the entire study area, on both sides of the Rio Grande. Changes in methods and objectives during the project primarily centered around remotely sensed data and the sensors used to analyze and classify riparian distribution. Although several remote-sensing systems, including CASI, SPOT, NASA EO-1, and videography (Table 1) were analyzed and/or evaluated, our primary remote-sensing tools were from the high-resolution airborne hyperspectral system HYMAP (Fig. 3), high resolution digital aerial photographs (DOQ's) (Fig. 4), and medium-resolution data from Landsat TM (Fig. 5).

Table 1. Remote-sensing data assembled and acquired by the Center for Space Research.

USDA large-scale CIR videography for 8 of the 10 vegetation-transect sites
Landsat TM imagery acquired in 1984, 1986, 1996, 1999, 2000, 2001, and 2002
SPOT imagery acquired in 1988, 1989, and 1990
AIRSAR and TOPSAR flight lines acquired in April 1998 from Bentsen-Rio Grande Valley State Park and westward
CASI (Airborne Hyperspectral 15-21 Bands => 400-800 nm, 2-4 m) acquired in 1999 of 7 transect sites
HYMAP (Airborne Hyperspectral 100+ bands => 400 – 2500 nm, 5 m) acquired in 1999 of 5 sites, and in 2002 of 3 sites.
41 digital orthophoto quadrangles (DOQ's) acquired in 1995 of the U.S. study area

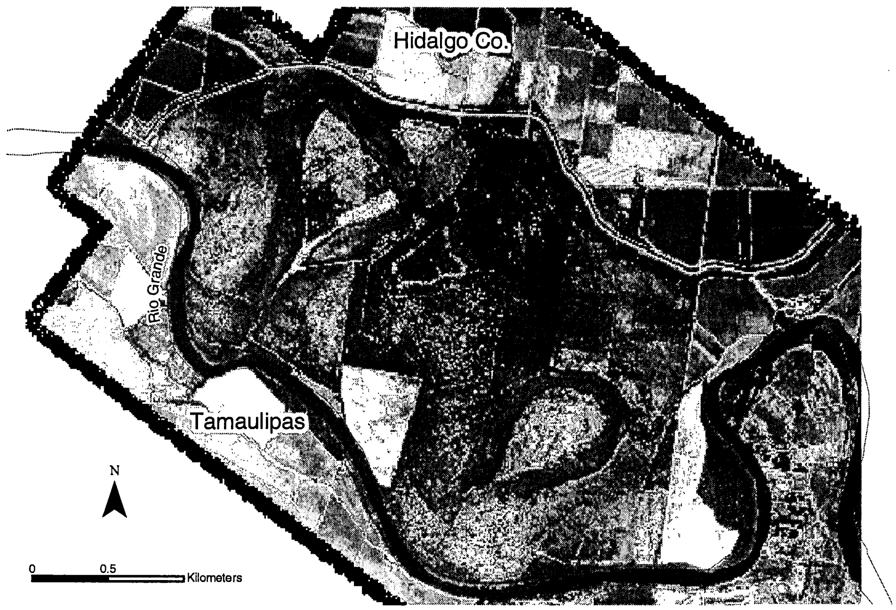

Figure 3. Color-infrared rendering of Hymap image at Bentsen State Park.

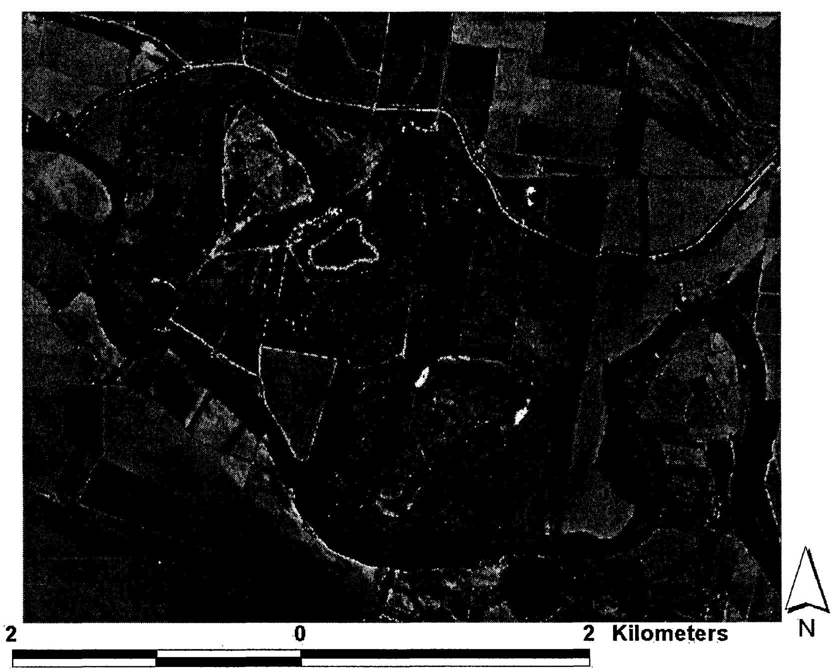

Figure 4. Example of Digital Orthophographic Quadrangle (DOQ) of Bentsen State Park.

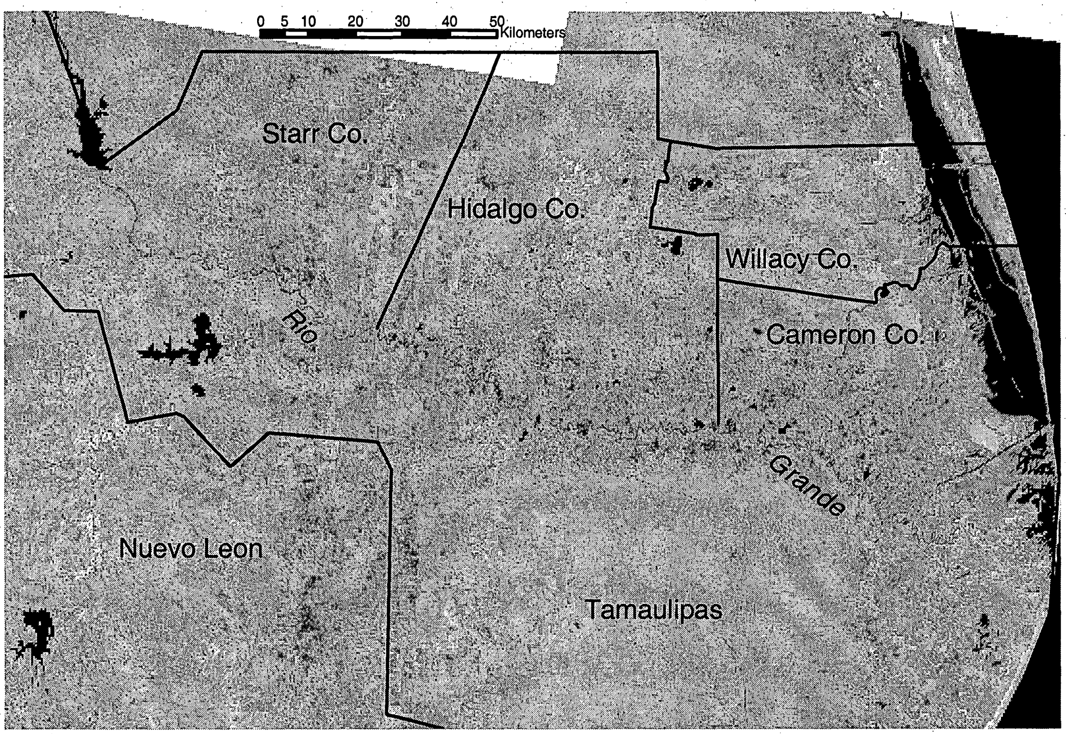

Figure 5. Landsat 7 ETM+ scenes used to classify and map riparian woodlands. The western scene was acquired on March 15, 2001, and the eastern scene February 23, 2002.

Topographic information from TOPSAR, as well as laser altimetry data acquired for the study, were investigated as additional inputs to the classification process and used to help explain temporal and spatial changes in ecological resources indicated in the remotely sensed data. Methodologically, we evaluated the potential benefits of multiple classification approaches, including multiresolution nueral networks, fuzzy Bayesian classifiers, and contextual classification algorithms. We used GIS-based spatial models and statistical modeling techniques to assess how information gathered at fine scales in intensive, local studies can be extrapolated to broad scales for ecological monitoring and landscape change analysis. Model results were used to predict the expected future effects of landscape change on plant distributions and community biodiversity and functional organization at multiple scales of resolution. Methodologies were developed to guide future assessments of riparian regions. This project helps link local, riparian data with regional remote sensing data in a unique location that is undergoing extensive environmental change, while providing opportunity to evaluate the potential for multiresolution analysis of an extensive multisensor, remotely sensed data set. We used field data of floodplain communities and both existing and additional remotely sensed data acquired for this project to map the entire riparian community along this reach of river.

To understand human influence on the Rio Grande correctly, we needed to account for changes on both sides of the river. Data from Mexico, however, was lower in detail than from the USA, or was unavailable. Decision-making is enhanced by understanding the riparian regions as a whole, not as one half the resource. Remotely sensed data can bridge the gap to some degree and show resource changes over extensive, inaccessible areas and across geopolitical boundaries. We used large-scale data collected over a small area in the USA to calibrate remotely sensed regional data, to then help quantify ecological resources across the border region and to understand changes occurring on both sides of the Rio Grande.

One element of the methodology was to use the interpretative advantages of a GIS to examine linkages between riparian ecology and various parameters (Table 2) such as geology (Fig. 6), surficial deposits (Fig. 7), topography (Fig. 8), soils (Fig. 9), water quality, hydrology (Figs. 10 and 11), precipitation, and land cover/land use. These kinds of data help evaluate temporal and spatial changes in riparian habitats and determine probable causes for changes. For example, lateral changes in soils may be responsible for changes in plant types and habitat. Landscape variables may also affect lateral changes. Temporal changes may be related to water quality changes such as increasing salinity due to agriculture. These data were considered during the interpretation of remotely sensed data to gain a better understanding of changes in ecological resources. Combined with the interpretive advantages of a GIS, an interdisciplinary partnership was employed between researchers in the different fields to examine linkages with the riparian ecology

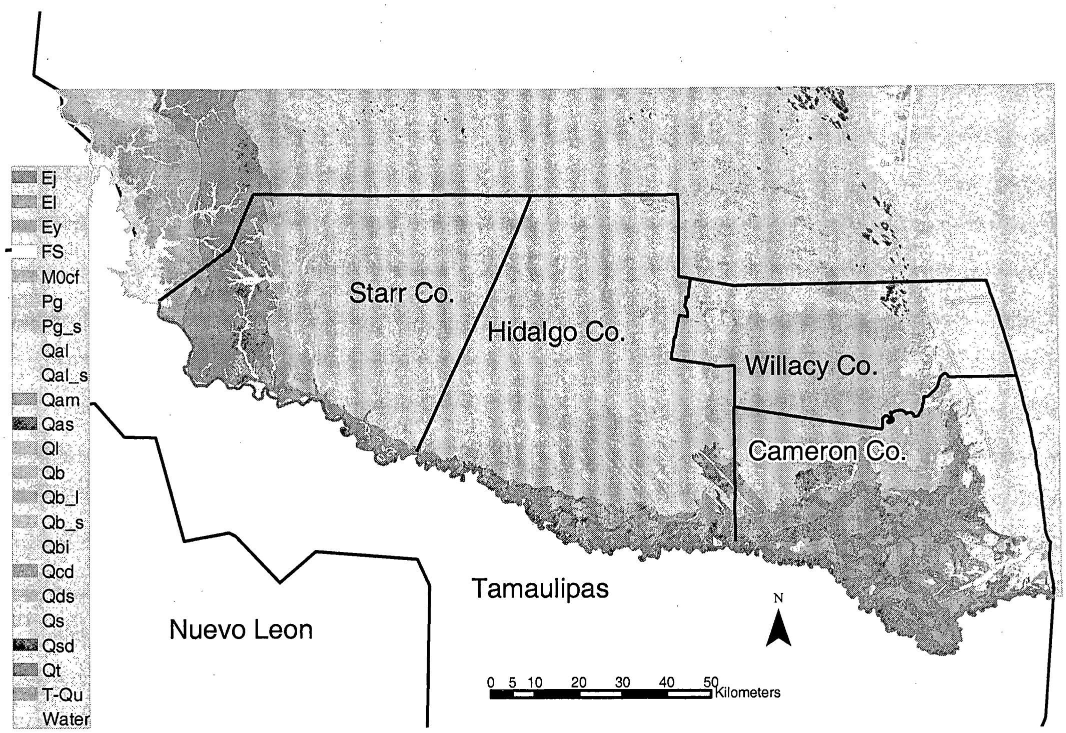

Figure 6. Geologic Atlas of Texas map sheet for the McAllen-Brownsville area (1:250,000). From Bureau of Economic Geology (1976).

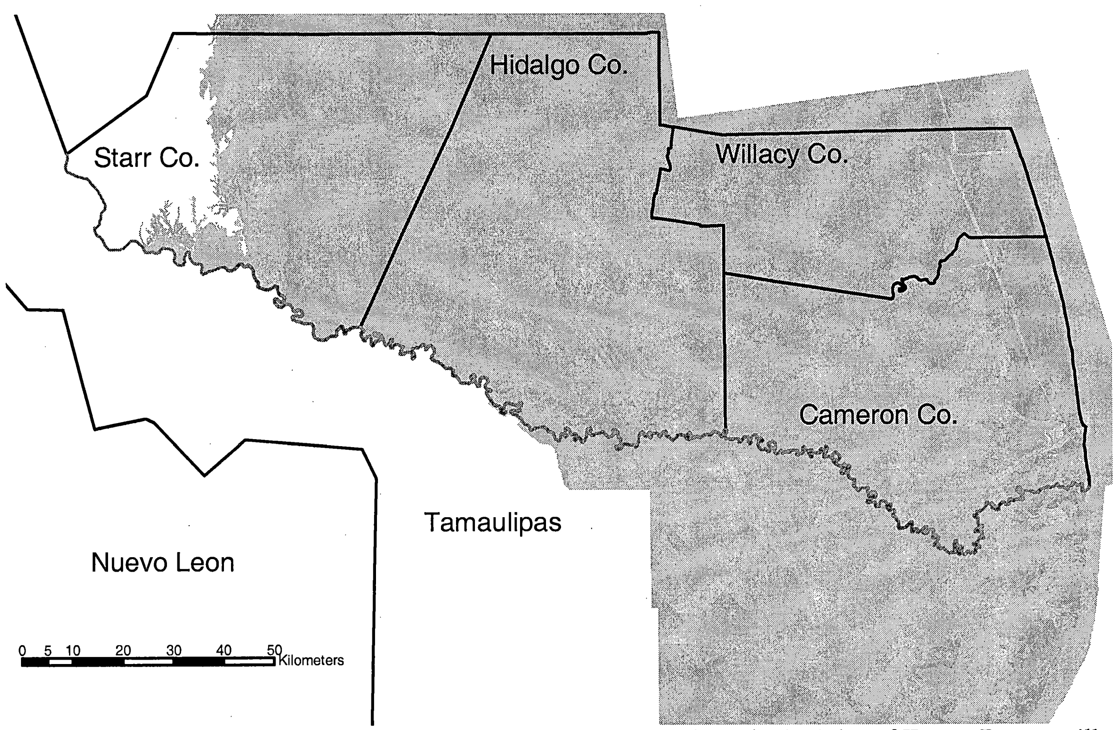

Figure 7. Surficial deposits map derived from the Environmental Geologic Atlas of Texas, Brownsville-Harlingen area. From Bureau of Economic Geology (1976).

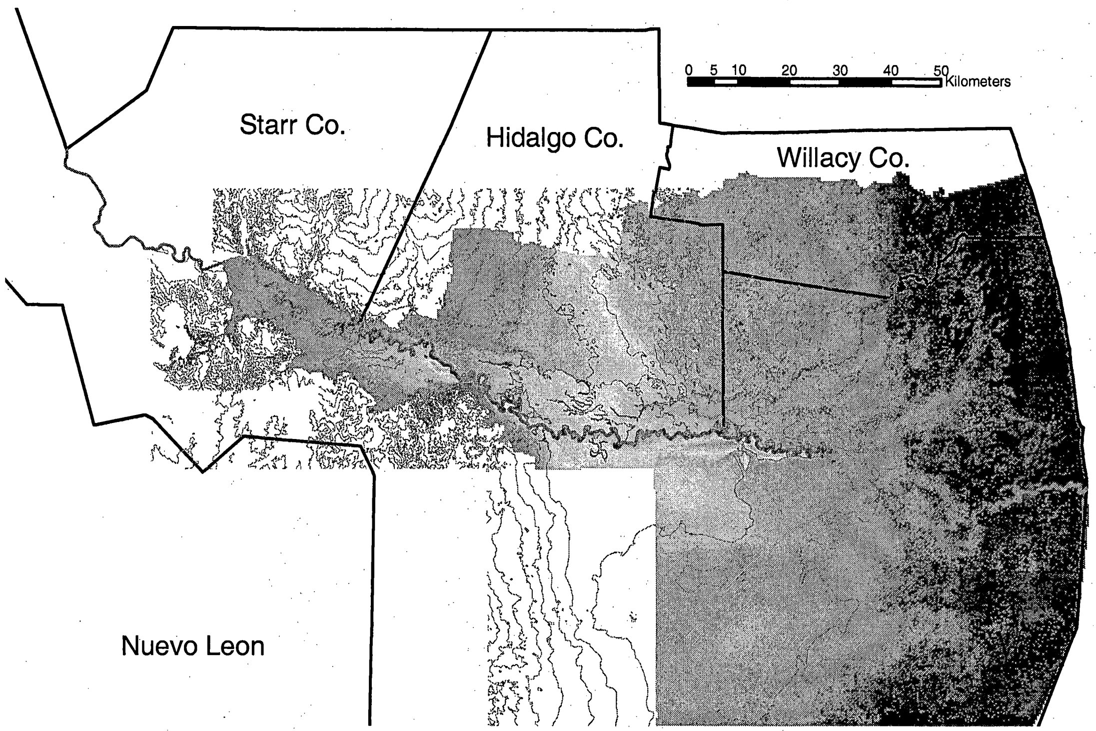

Figure 8. Elevation data in study area. Color-ramped grid of National Elevation Dataset (NED) and superimposed contour data captured from topographic maps.

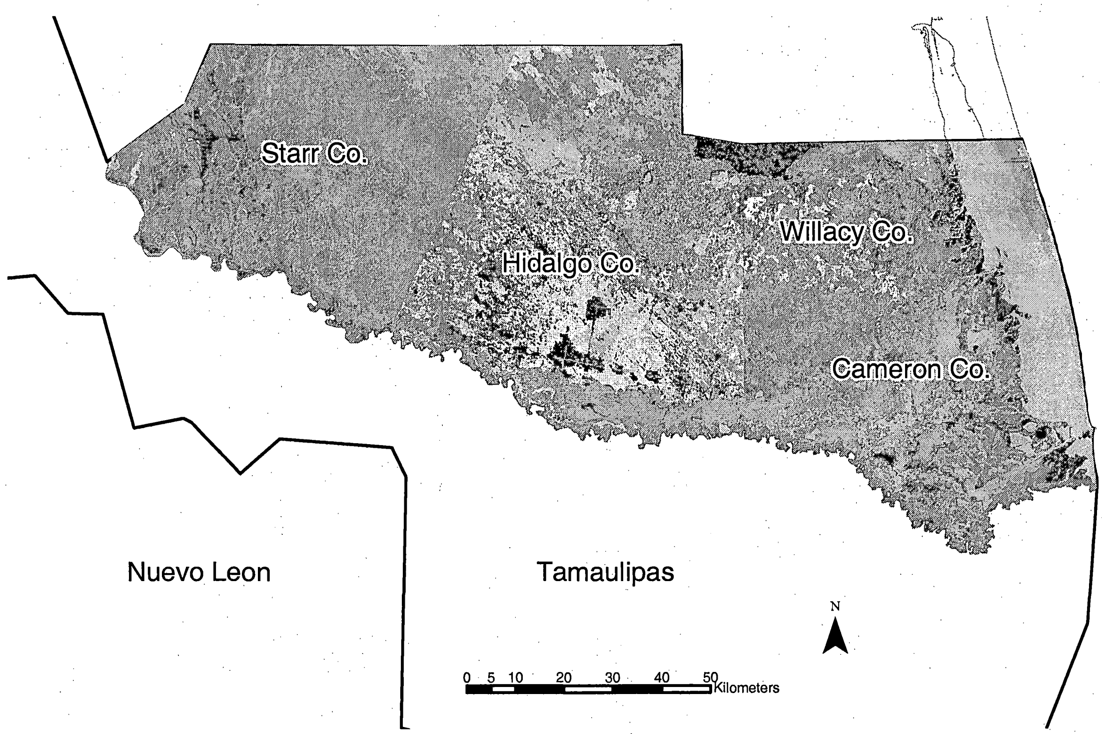

Figure 9. Natural Resources Conservation Service (NRCS) soils map for the LRGV (1:24,000). Derived from U.S. Department of Agriculture Natural Resources Conservation Service SSURGO database.

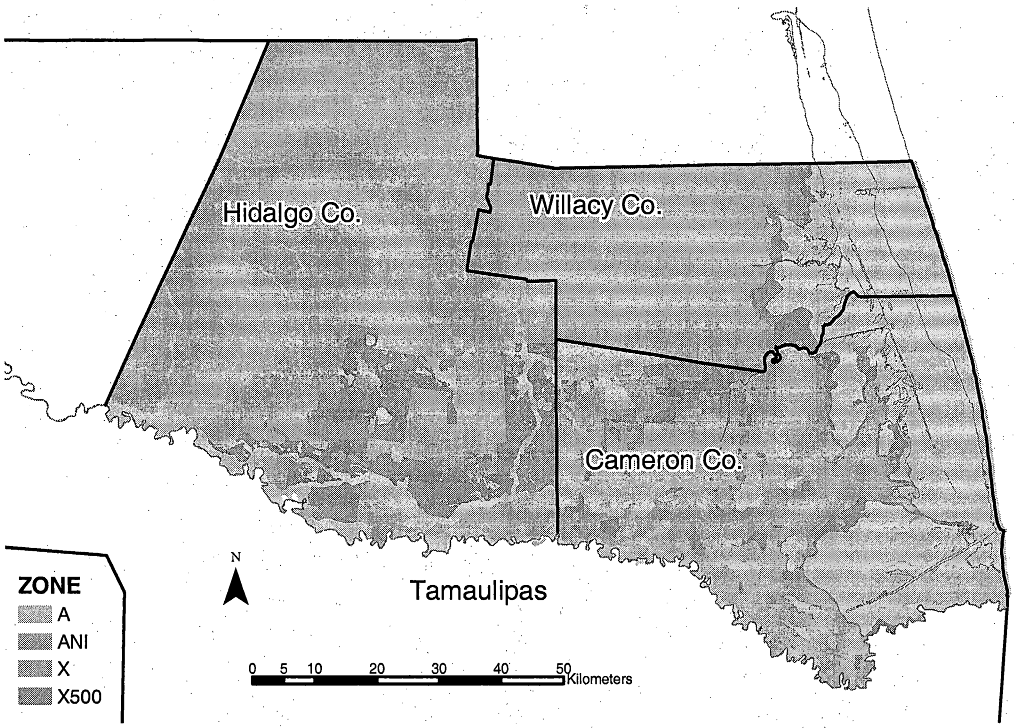

Figure 10. Federal Emergency Management Agency (FEMA) Special Flood Hazard Areas.

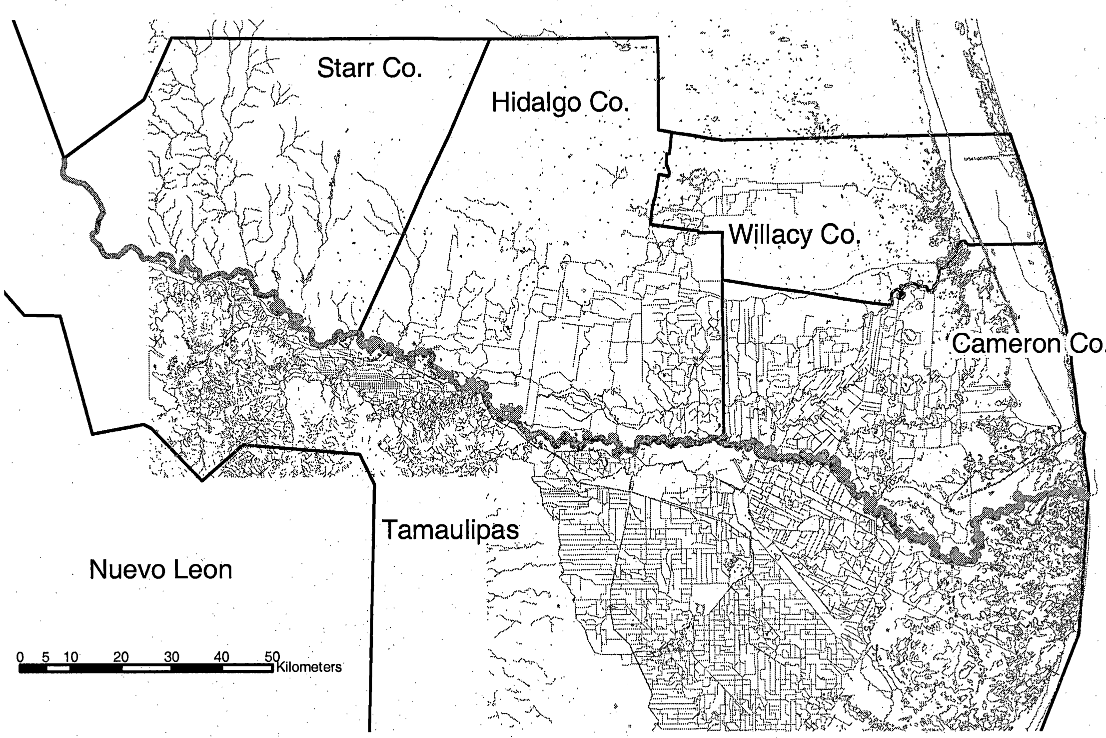

Figure 11. USGS digital line graph files in the US portion of the study area (1:100,000). Mexico hydrography captured from 1:50,000 scale INEGI topographic maps.

Table 2. GIS layers that were compiled in the U.S. and Mexico to examine linkages between riparian ecology and various parameters included these elements.

Geology (U.S.; Mexico)
Surficial Deposits (U.S.)
Soils (U.S.)
Lithology and texture
Salinity
Drainage capacity
Flood frequency
Shrink-swell
Flood frequency (FEMA) (U.S.)
Land cover/land use
Current (U.S.)
Historical (U.S.)
Riparian distribution
Current (U.S.; Mexico)
Historical (U.S.)
Species composition at field sites (U.S.)
Topography (U.S.)
Topographic maps
Digital Elevation Models
LIDAR (selected areas)
Hydrology (U.S.; Mexico)
Groundwater, total dissolved solids (U.S.)
Wetlands (include fluvial woodlands and forested wetlands) (U.S.)
Lower Rio Grande National Wildlife Refuge tracts (acquisitions by USFWS)

Vegetation Surveys

UT-Pan Am investigators surveyed riparian vegetation at eight transects previously established along the Rio Grande between the mouth of the river and Falcon Dam, a distance of over 200 km. With the addition of new sites, a total of eleven sites were surveyed. From the Rio Grande upstream the sites are (1) Mouth of the Rio Grande, (2) Palmito Pumphouse, (3) Sabal Palm Sanctuary, (4) Santa Maria, (5) McManus Unit, (6) Santa Ana NWR, (7) Anzalduas Park, (8) Bentsen-Rio Grande Valley State Park, (9) La Joya, (10) Escobares, and (11) Salineño (Fig. 12). New transect sites were those at Escobares, located between the existing sites of Salineño and La Joya along the upper reaches of the study area, and at McManus Unit of the Texas Parks and Wildlife Department located approximately 8.2 km east of the Santa Ana National Wildlife Refuge and 1.2 km north of the Rio Grande in Hidalgo County. Except for the McManus Unit (discussed below), sampling methods used in the vegetation surveys were the same as at previously established sites and included establishing three parallel transects (at least 10 m apart). Transects began at the river's edge and extended at a right angle up the river bank and across the first terrace to the second terrace of the river or until there were no more trees, whichever occurred first. The line-intercept method of vegetation analysis was used (Canfield, 1941). Transects were subdivided into 10-m intervals, and readings were taken along the total length of each interval. Each species intercepted by the line was rated individually and scored with separation into strata. Trees were 3.0 m or taller, shrubs were 1.0 to 2.9 m, and the ground layer was less than 1.0 m. Foliage cover and frequency of occurrence were recorded and from these data relative cover, relative frequency, and an importance value that was the sum of relative cover and relative frequency were calculated. Importance values were used to determine dominant species. A comparison of dominant species between years at the sites and quantification of abundance was determined and summarized in tables.

The McManus Unit of the Texas Parks and Wildlife Department is undisturbed native woodland but within the historical floodplain of the river. Methods used by UT-Pan Am investigators to census vegetation at this site were different from the methods discussed above. To census the vegetation, ten 10 m by 10 m quadrats were established at randomly determined locations. Censusing of tree, shrub, and ground layers was done separately. The tree layer consisted of woody plants greater than 3.0 m tall. The shrub layer was comprised of woody plants 1.0 to 3.0 m tall. The ground layer consisted of herbaceous and woody plants less than 1.0 m tall. Density of trees and shrubs was counts of individuals in the quadrats. Frequency was determined by the presence of a species in the 10 quadrats of the site. Cover was based on diameter at breast height (dbh = 1.35 m) of trees and the basal diameter of shrubs. Multiple stems were summed. Dominance in the tree and shrub layers was determined by calculating an importance value, which was the sum of relative density, relative frequency, and relative cover. Heights of trees and shrubs were determined using a calibrated telescoping pole that had a maximum height of 7.5 m. Height of trees taller than 7.5 m was estimated. The ground layer was censused using the line intercept technique (Canfield, 1941). Five 10 m long intervals were established spaced 2 m apart across each quadrat. Thus, there were 50 intervals. Cover was determined by the perpendicular projection of the foliage onto the transect line. Frequency was based on the presence of a species in the 50 intervals of the transects. To determine the density of tree and shrub seedlings, a 10 cm strip on each side of the transect was established. Density and height of tree and shrub seedlings less than 1.0 m tall were determined in the 20 cm wide belts. For all other ground layer species, density was not determined because of the difficulty in identifying what constituted an individual. Dominance was assessed in the ground layer by calculating an importance value that was the sum of relative frequency and relative cover.

In addition to transect surveys of vegetation, vegetation communities were examined at over 77 field sites that were located on CIR aerial photographs between Santa Ana National Wildlife Refuge and Brownsville (Fig. 13 and Appendix 1). These sites were characterized in terms of vegetation assemblages keyed to species level. Also, 27 additional field sites in the Santa Ana National Wildlife Refuge were examined and characteristic vegetation recorded, and 43 sites at Bentsen-Rio Grande Valley State Park (Fig 14). On the basis of dominant vegetation and CIR signatures, most sites were

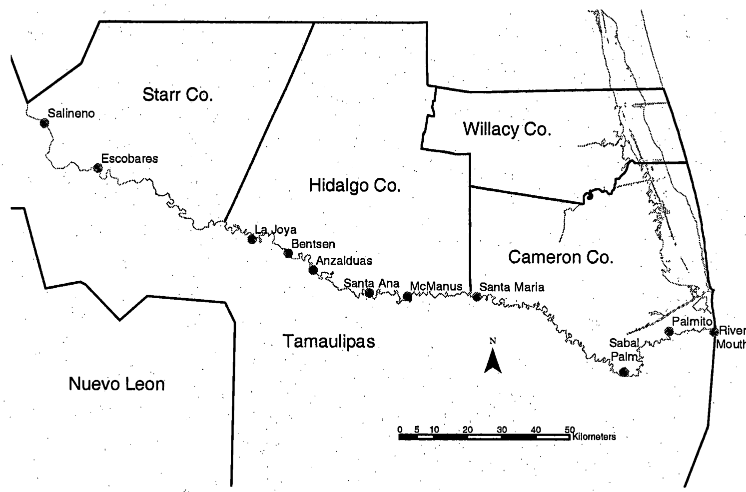

Figure 12. Location of eleven vegetation transect sites along the Rio Grande occupied by scientists from UTPanAm.

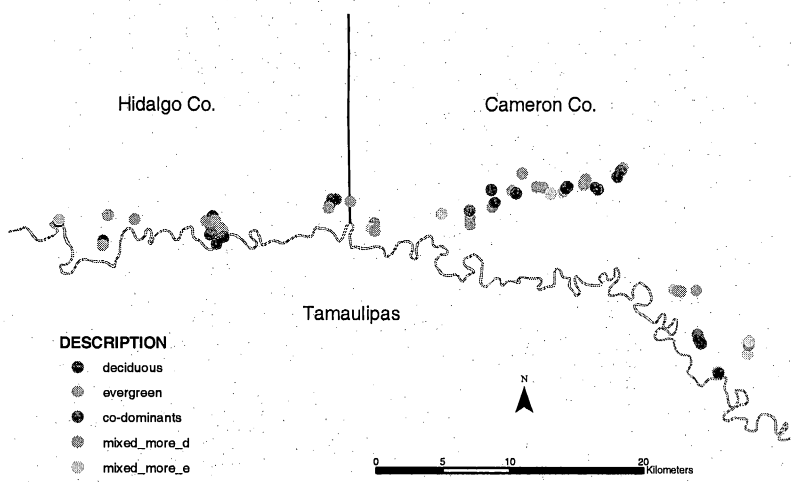

Figure 13. Field sites where vegetation species were inventoried. Field site locations allowed spatial analysis of species-soils relationship, and provided additional training sites for computer analysis.

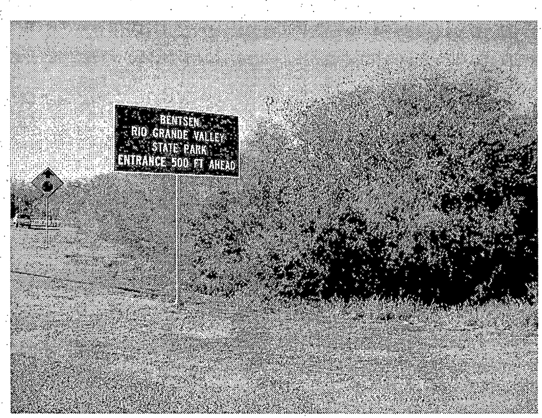

Figure 14. Photograph of entrance to Bentsen State Park.

classified in terms of their evergreen and deciduous make-up, as described in a following section.

Land Use, Soils, and Climate Mapping

Among the results of a previous cooperative study between UTB and BEG was the compilation of a GIS data base, which was utilized in the current EPA project. Layers relating to the Lower Rio Grande Valley include land use in 1960 and a seamless, digital, geologic map, based on INEGI 1:250,000 quads, for the area from Cd. Juarez, Chihuahua, to Matamoros, Tamaulipas. The 1960 land-use map (Fig. 15), digitized at a scale of 1:24,000, served as a base for comparison with current land-use mapping. Current land-use and soils mapping of the Lower Rio Grande Valley of Texas and northeast Mexico was begun in January 2000 by investigators at UTB. A current land-use map for the Lower Rio Grande Valley (Fig. 16) was completed on the basis of both field observation and the use of USGS DOQ's. The area mapped stretches from Falcon Dam in the northwest, to Arroyo Colorado in the northeast, and to the mouth of the Rio Grande in the southeast. Methods included (1) conducting field surveys for familiarity, (2) interpreting and classifying land use on DOQ's, and (3) drawing polygons according to land use types. The basis for classification is a modified Anderson land-use classification (Anderson and others, 1971) utilized by the BEG in a land-use map based on 1960's photographs. Polygons were assigned first, according to the older classification for comparability, then a subclassification was employed for greater detail. After initial DOQ classification, the area was again field surveyed for greater accuracy. The result was a digital land-use map. The polygons were digitized by means of the Cartalinx program then exported to ArcView for map composition. The land-use map was done in several layers. The first layer consisted of large polygons, such as urbanization, agriculture, and range-pasture, for the purpose of (1) showing immediate visual comparison and (2) keeping the map from being too cluttered. The second layer showed smaller units, such as education sites, recreation, land fill, etc. The map is based on the 1995 DOQ's but has an updated (2000) layer based on current field surveys.

A soils data base for the Mexico side of the Rio Grande was also constructed (Fig. 17). INEGI soils maps, scale of 1:50,000, were digitized in the zone from Falcon Dam to the mouth of the Rio Grande. The soils classification involved a classification scheme that was older than the one currently used by the USDA. Difficulties included translating the Mexican soils data to insure compatibility/comparability with U.S. data.

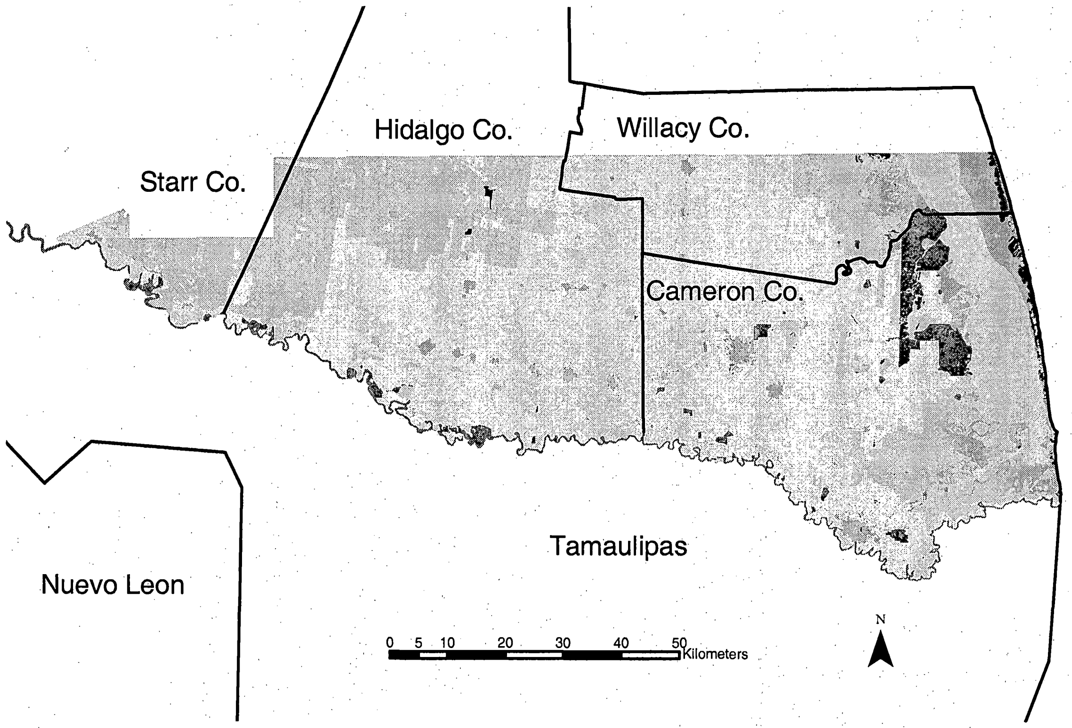

Figure 15. 1960 Landuse map derived from the Environmental Geologic Atlas of Texas. From Brown and others (1980).

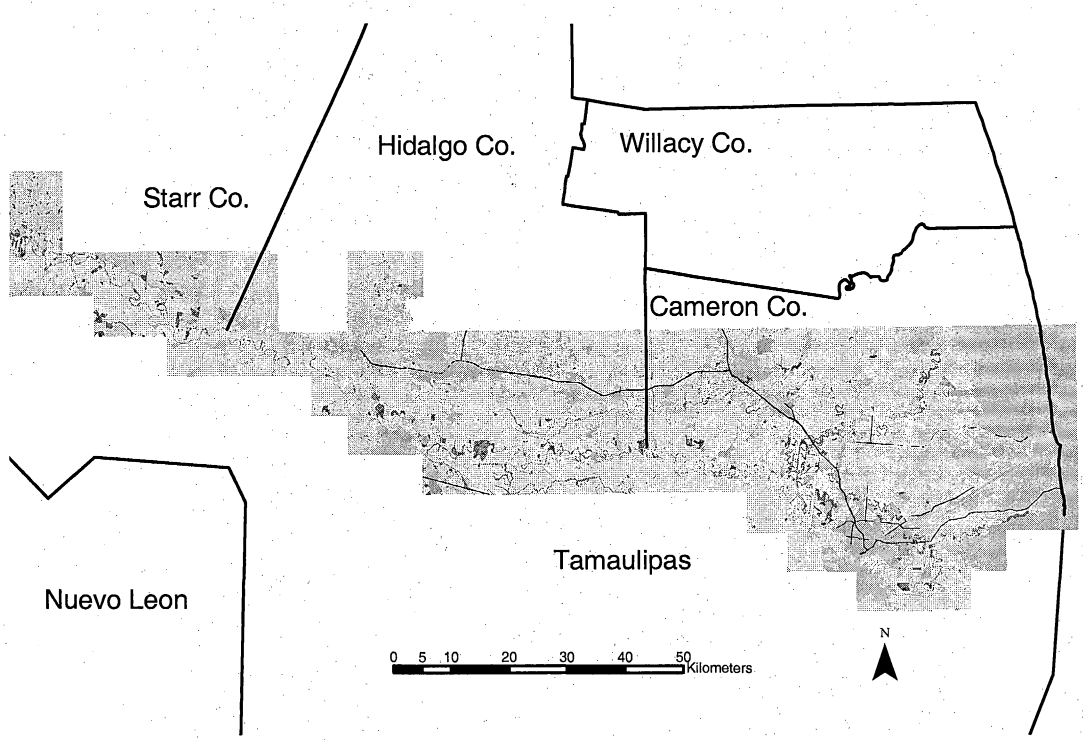

Figure 16. Current (1995) land use and land cover map interpreted from color infrared DOQs.Fig

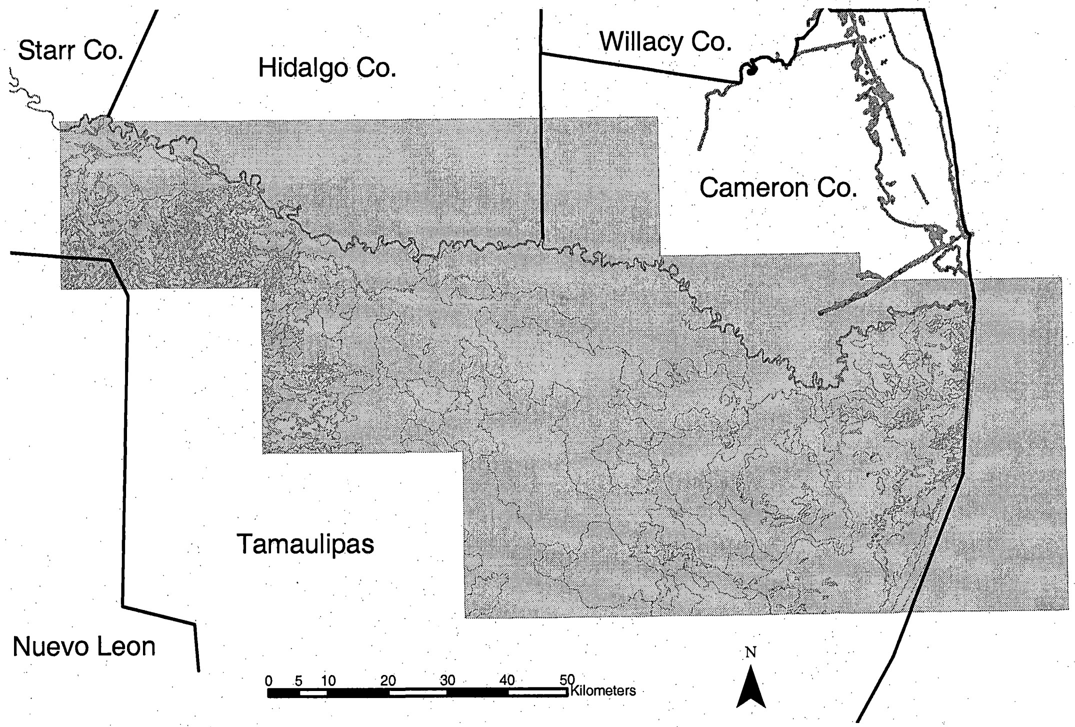

Figure 17. Map showing soil boundaries in Mexico.

The specific Digital Orthophotoquads (DOQ's), for which land-use coverage was digitized at a scale of 1:18,000, include the following: Roma–Los Saenz West, Roma–Los Saenz East, Los Garzas, Rio Grande City North, Rio Grande City South, La Grulla, Los Ebanos NW, Sullivan City, Los Ebanos, Citrus City, La Joya, Alton, Mission, Hidalgo, Edinburg, Pharr, Las Milpas, Donna, San Juan, Mercedes, Progreso, La Feria, Santa Maria, Harlingen, La Paloma, Rio Hondo, Olmito, West Brownsville, Laguna Atascosa, Los Fresnos, East Brownsville, Southmost, La Coma, Laguna Vista, Palmito Hill, Port Isabel NW, Port Isabel, and Mouth of the Rio Grande.

The digital land-use map was transferred to the Bureau of Economic Geology (BEG) where it was entered into our GIS. The map was also distributed to the Center for Space Research (CSR) for their use as collateral data in classifying riparian vegetation distribution using Landsat TM data.

In addition, maps on climate (average annual precipitation, September precipitation, average annual temperature, January mean temperature, July mean temperature, heating degree days, and cooling degree days) completed by UTB were entered into BEG's GIS for analysis (Figs. 18 and 19). The climatic maps show systematic variations in precipitation and temperature in the study area including "heat islands" encircling metropolitan centers.

RESULTS AND DISCUSSION

Vegetation Surveys

The University of Texas-Pan American (UT-PanAm) at Edinburg reported on the riparian vegetation of the lower reach of the Rio Grande based on samples obtained at 7 existing localities between the mouth of the river in Cameron County and Falcon Dam in Starr County, and at 4 new sites established along the river (Fig. 12). They also provided ground truth on vegetation composition at more that 150 additional sites and subsites for remote sensing analysis. Changes in vegetation between 1993 -1995 and 2000 are provided for the 7 existing sites along the Rio Grande. UT-PanAm scientists tried to place transects in the same places in 2000 that were sampled in 1993 -1995 and were largely successful in doing so. However, there may have been slight differences in the placement of some transects. Following are discussions of re-surveyed sites in Lonard and Judd (2002).

Existing Riparian Sites Surveyed (See Appendix 2 for transect data)

Mouth of the River - As in 1993, there were no trees at the mouth of the Rio Grande in 2000. Black mangrove (*Avicennia germinans*) was the only shrub present and it had increased in abundance in the intervening 7 years. The increase in abundance of black mangrove probably reflects an absence of freezes between 1993 and 2000.

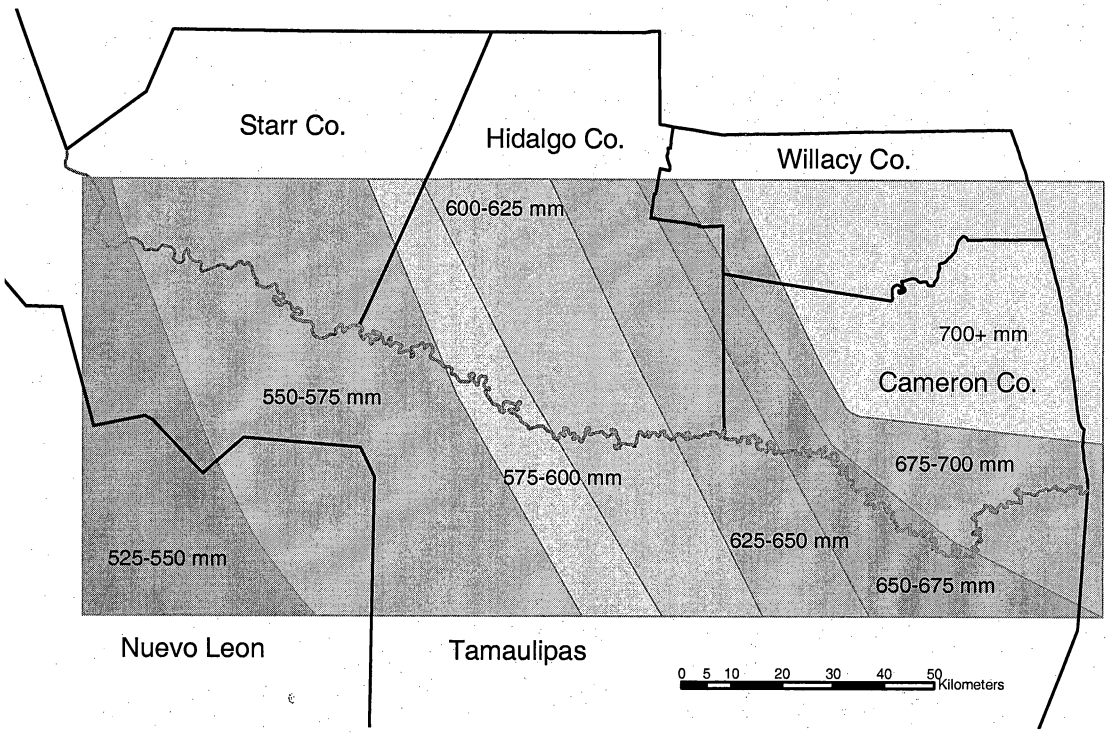

Figure 18. Map of annual precipitation in the Lower Rio Grande Valley (LRGV). Annual precipitation decreases from 700 mm near the coast to 540 mm at Falcon Dam.

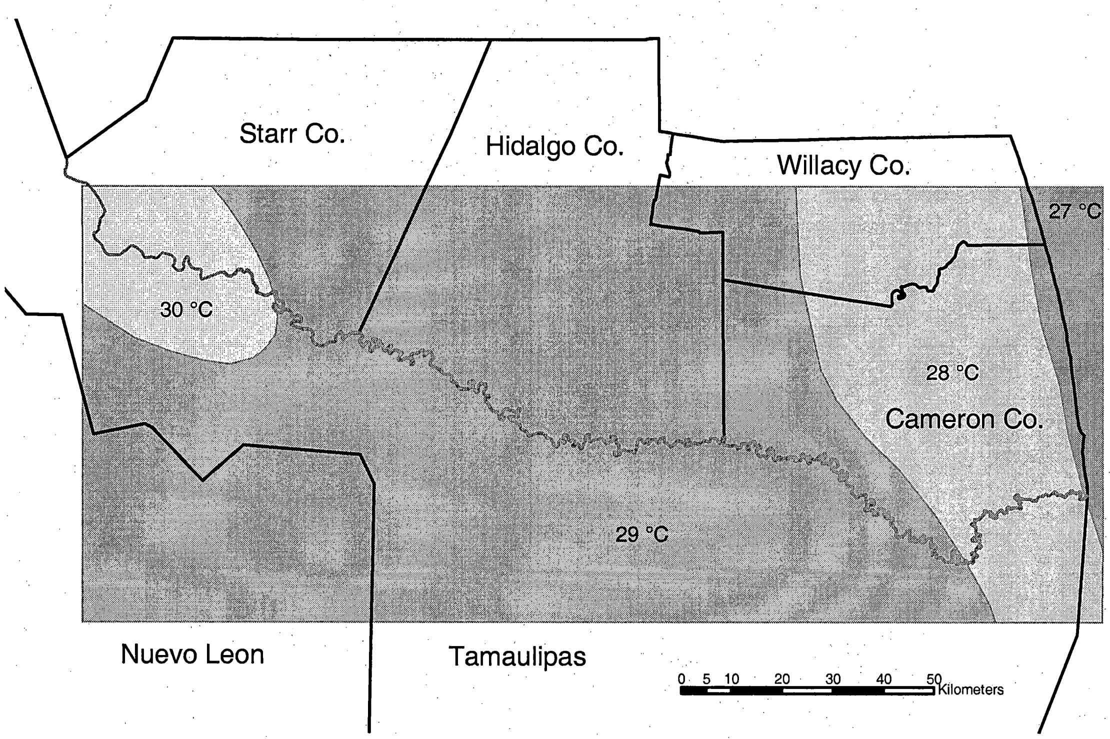

Figure 19. Map of mean temperature during July. Mean at the coast is 28.5° C, further inland at Roma and Rio Grande City means are over 30° C.

The mouth of the river appears to have shifted northward slightly and eroded the north bank of the river at our transect sites. This may have resulted in a decrease in the abundance of shoregrass (*Monanthochloe littoralis*) which was dominant in the ground layer in 1993. Saltwort (*Batis maritima*) was the dominant in the ground layer at this site in 2000. This site is subject to disturbance by motor vehicles.

Palmito Pumphouse - Mesquite (*Prosopis glandulosa*) was the dominant tree at Palmito Pumphouse in 1993 and 2000, but there were changes in the shrub and ground layers. Change in the shrub layer was relatively slight. Granjeno (*Celtis pallida*) ranked first in importance in 1993 while in 2000, it ranked third in importance. Snake-eyes (*Phaulothamnus spinescens*) ranked third in importance in 1993 and in 2000, it was the dominant species. Colima (*Zanthoxylum fagara*) ranked second in importance in both 1993 and 2000.The decrease in abundance of granjeno in the shrub layer appears to have been due, in part, to the growth of individuals in the transects to tree height. Change in the ground layer was marked. The introduced Guinea grass (*Panicum maximum*) replaced shoregrass (*Monanthochloe littoralis*) as the dominant species. In 1993, Guinea grass only ranked fifth in importance in the ground layer and had a relative cover of only 4.9 %. In 2000, it ranked first in importance and had a relative cover of 38.5 %. Thus, Guinea grass increased in cover almost 8 fold in the intervening 7 years.

Sabal Palm Sanctuary - Guinea grass (*Panicum maximum*) was the dominant species in the ground layer at the Sabal Palm Sanctuary in both 1993 and 2000. Similarly, sugar hackberry (*Celtis laevigata*) was the dominant species in the tree layer in both 1993 and 2000. There were important changes in the shrub layer at this site. Common reed (*Phragmites australis*) replaced sugar hackberry as the dominant species and giant reed (*Arundo donax*), which was not encountered in 1993, ranked third in importance with an importance value close to that of sugar hackberry.

Santa Ana National Wildlife Refuge. Guinea grass (*Panicum maximum*) was the dominant species in the ground layer in both 1993 and 2000. Colima (*Zanthoxylum fagara*) was the dominant species in the shrub layer in 1993, but in 2000, common reed (*Phragmites australis*) was dominant. This change may reflect an increase in abundance of common reed and slightly different placement of transects in the two years. Colima only ranked sixth in importance in the shrub layer in 2000. Cedar elm (*Ulmus crassifolia*) was the dominant tree in 1993, but in 2000 Rio Grande ash (*Fraxinus berlandieriana*) was dominant at this locality. This difference surely is due to differences in the placement of transects.

Anzalduas. There was little change in the vegetation layers at the Lower Rio Grande Valley National Wildlife Refuge near Anzalduas Dam. Guinea grass (*Panicum maximum*) was the dominant species in the ground layer in 1994 and 2000. Similarly, sugar hackberry (*Celtis laevigata*) was the dominant tree in 1994 and 2000 at this site. Granjeno (*Celtis pallida*) was the dominant species in the shrub layer in 1994, but in 2000 common reed (*Phragmites australis*) was dominant and granjeno was second in importance.

Bentsen-Rio Grande Valley State Park. Each vegetation layer had the same dominant species in 1995 and 2000. Guinea grass (*Panicum maximum*) was dominant in the ground layer. Granjeno (*Celtis pallida*) was dominant in the shrub layer and sugar hackberry (*Celtis laevigata*) was dominant in the tree layer.

Salineño. Each vegetation layer had the same dominant species in 1995 and 2000. The introduced grass, *Pennisetum ciliare,* (buffel grass) was the dominant species in the ground layer. Granjeno (*Celtis pallida*) was the dominant in the shrub layer and mesquite (*Prosopis glandulosa*) was dominant in the tree layer.

Introduced grasses are dominant in the ground layer at six of the 7 sites we sampled. Native species are dominant in the ground layer only at the mouth of the river where there is no riparian vegetation. Buffel grass was dominant at only one site in the westernmost reach of the lower Rio Grande near Falcon Dam and where the flood plain of the river is narrow.

Increase in abundance of common reed (*Phragmites australis*) and giant reed (*Arundo donax*) along the Rio Grande may reflect low water levels and sluggish flow. Indeed, the Rio Grande no longer flows to the Gulf of Mexico. Everitt et al. (1999) reported that two exotic aquatic macrophytes , waterhyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata*) have increased in abundance in the Rio Grande in recent years slowing its flow. Additionally, a protracted drought has drastically lowered water in Falcon and Amistad lakes resulting in decreased releases of water for agricultural purposes. We suggest that the slow flow contributes to the establishment and growth of reeds along the banks of the river.

New Riparian Sites Surveyed (See Appendix 3 for transect data)

Santa Maria. This site is located between the Sabal Palm Sanctuary and Santa Ana National Wildlife Refuge (NWR) of Lonard and Judd (2002). It is 29 km east of Santa Ana NWR. The dominant species in the tree layer is sugar hackberry, *Celtis laevigata* (Table 1 in Appendix 3). This is consistent with the findings of Lonard and Judd (2002) who reported sugar hackberry was the dominant tree species at three of four locations in the mid-reach of the lower Rio Grande.

Sugar hackberry also was the dominant species in the shrub layer at Santa Maria (Table 1 in Appendix 3) and it was present as a seedling in the ground layer. Clearly the dominant tree is reproducing successfully at Santa Maria and all stages of the life cycle are represented. The only site reported by Lonard and Judd (2002) where sugar hackberry was a dominant in the shrub layer was the Sabal Palm Sanctuary.

Guinea grass (*Panicum maximum*) was the dominant species in the ground layer (Table 2 in Appendix 3). The first three species in importance, i.e. *Panicum maximum, Clematis drummondii* and *Rivina humilus* contributed 81.6 % of the relative cover and 21 additional species provided the remaining 18.4 % of the relative cover. Lonard and Judd

(2002) found that *Panicum maximum* was dominant at all 4 sites in the mid-reach of the lower Rio Grande. The site upstream of Santa Maria (Santa Ana NWR) and downstream (Sabal Palm Sanctuary) also had *P. maximum* as the dominant species in the ground layer (Lonard and Judd, 2002).

Species richness in the tree layer at Santa Maria (8) is lower than at sites upstream, Santa Ana NWR, (10) and downstream, Sabal Palm Sanctuary (10).
Species richness is even lower in the shrub layer at Santa Maria. There are only 5 species present. This compares to 12 species at Santa Ana NWR and 11 species at Sabal Palm Sanctuary. Species richness in the ground layer at Santa Maria (24) is similar to that at Sabal Palm Sanctuary (22), but far lass than at Santa Ana (35).

La Joya. This site is located between Bentsen-Rio Grande Valley State Park and Salineño of Lonard and Judd (2002). It is 13.3 km west of Bentsen-Rio Grande Valley State Park. As at Bentsen-Rio Grande Valley State Park, the next site down river, sugar hackberry (*Celtis laevigata*) is the dominant species in the tree layer at La Joya (Table 3 in Appendix 3). Granjeno (*Celtis pallida*) is a dominant species in the shrub layer at La Joya (Table 3 in Appendix 3) as it is in the next site downstream (Bentsen-Rio Grande Valley State Park) and upstream (Salineño) (Lonard and Judd, 2002). However, at La Joya Rio Grande ash, *Fraxinus berlandieriana*, was a co-dominant in the shrub layer (Table 3).

Guinea grass (*Panicum maximum*) is the dominant species in the ground layer at Bentsen-Rio Grande Valley State Park (Lonard and Judd, 2002), but it was third in importance at La Joya (Table 4 in Appendix 3). The dominant species in the ground layer at La Joya is the vine, Texas virgin's bower (*Clematis drummondii*). Plains bristlegrass (*Setaria leucopila*), a native species, was the most important grass at La Joya. It ranked second in importance in the ground layer (Table 4 in Appendix 3).

Species richness was greater in the tree layer at La Joya (10) than at Bentsen-Rio Grande Valley State Park (7) or Salineño (8). Species richness in the shrub layer was three fold greater at La Joya (16) than at Bentsen-Rio Grande Valley State Park (5) or Salineño (5).Species richness in the ground layer at La Joya (34) was similar to that at Salineño (35), but markedly greater than at Bentsen-Rio Grande Valley State Park (7).

Escobares. Escobares is located between La Joya and Salineño of Lonard and Judd (2002). It is 19.3 km E of Salineño.The nearest site upriver from Escobares was Salineño and the nearest site downriver was La Joya. Escobares and Salineño had the same dominant species in each layer of vegetation. Conversely, Escobares had different dominant species in the tree and ground layers than La Joya.

The dominant species in the tree layer at Escobares was mesquite, *Prosopis glandulosa*, (Table 5 in Appendix 3) as it was at Salineño (Lonard and Judd, 2002). Similarly, the dominant species in the shrub layer at Escobares was granjeno,*Celtis pallida*, (Table 5 in Appendix 3) as it was at Salineño (Lonard and Judd, 2002). Buffel grass (*Pennisetum ciliare*) and seedlings of sugar hackberry (*Celtis laevigata*) were co-dominants in the ground layer at Escobares (Table 6 in Appendix 3). Buffel grass also was dominant in the ground layer at Salineño (Lonard and Judd, 2002).

Species richness in the tree layer was lower (5 species) at Escobares than at Salineño (8 species). Both Escobares and Salineño had 5 species in the shrub layer. Escobares had about half as many species in the ground layer (16) as at Salineño (35).

McManus Unit. The McManus Unit of the Texas Parks and Wildlife Department is located 1.2 km north of the Rio Grande, but within the historical floodplain of the river. Different sampling methods were used at this site (described above) so as to provide information on density of trees and shrubs. This site is 8.2 km east of the eastern boundary of Santa Ana NWR. Granjeno (*Celtis pallida*) was the dominant species in the tree layer at McManus Unit (Table 7 in Appendix 3). This is unusual for granjeno is usually considered a shrub. However, mean height of granjeno at the McManus site is slightly over 3.0 m (i.e. 3.78 m). Because granjeno barely exceeded the standard that we established for the maximum height of shrubs, it may be appropriate to consider bumelia (*Sideroxylon celastrium*) which was second in importance in the tree layer as the dominant tree. Cedar elm (*Ulmus crassifolia*) was third in importance at the McManus site. It is a dominant tree at the nearby Santa Ana NWR site (Lonard and Judd, 2002), thus, its relatively high importance at the McManus Unit is not surprising.

Snake eyes (*Phaulothamnus spinescens*) and chapotillo (*Amyris texana*) are co-dominants in the shrub layer (Table 8 in Appendix 3). Neither of these species was present in the shrub layer at the nearby Santa Ana NWR (Lonard and Judd, 2002) and only snake eyes was present at one of the seven sites (Palmito Pumphouse) we examined along the Rio Grande (Lonard and Judd, 2002).

Granjeno (*Celtis pallida*) is often the dominant shrub in sites along the Rio Grande, but it ranked 7th in importance in the shrub layer at the McManus site. This is due to the high numbers of granjeno in the tree layer. If the individuals in the tree layer were added to the individuals in the shrub layer, granjeno would have been the dominant shrub.

Crucita (*Chromolaena odorata*) was the dominant species in the ground layer and the introduced grass, Guinea grass, (*Panicum maximum*) was second in importance (Table 9 in Appendix 3). At nearby Santa Ana NWR, Guinea grass was dominant and crucita was fifth in importance (Lonard and Judd, 2002). Plains bristle grass (*Setaria leucopila*), a native species, reaches relatively high importance in the ground layer at the

The McManus site (Table 9 in Appendix 3) is not a close match in species composition or structure to any of the seven sites studied by Lonard and Judd (2002) along the Rio Grande. It also differs considerably from a native woodland site described by Judd et al. (2002a) at a place 33 km northeast in Cameron County. Apparently, there is a change in communities in less than 1.2 km distance from the river.

General Discussion of Vegetation

Data from the new sites confirmed that mesquite is the dominant tree in the riparian zone of the lower reach of the Rio Grande from the point where trees begin to be present, i.e. at Palmito Pumphouse to a point between Palmito Pumphouse and the Sabal Palm Sanctuary. Mesquite also is the dominant tree in the western part of the riparian zone from a point between La Joya and Escobares. In the mid portion of the lower reach of the Rio Grande from Sabal Palm Sanctuary to a point between La Joya and Escobares, sugar hackberry is the dominant tree at all sites except Santa Ana NWR. Thus, mesquite is dominant in the western portion of the lower reach of the Rio Grande where rainfall is least and where the flood plain of the river is narrow. Mesquite also is dominant in the easternmost portion of the lower reach of the Rio Grande where soil salinity and wind-blown salt spray are greatest.

The present riparian communities may be greatly influenced by human interventions such as construction of dams that have eliminated annual flooding of the Rio Grande. Blair (1950) reported that cedar elm (*Ulmus crassifolia*) was the dominant tree in the floodplain of the Rio Grande in the Lower Rio Grande Valley of Texas. We found cedar elm was a dominant species only at Santa Ana NWR (Lonard and Judd, 2002). This species' distribution and abundance may have been adversely affected by the curtailment of annual flooding of the Rio Grande. Certainly, it is no longer a widespread dominant species in the riparian zone of the lower reach of the Rio Grande.

A riparian community not sampled in this study or by Lonard and Judd (2002) is the Texas Palmetto community. It has been recognized as distinct by Clover (1937), Davis (1942), Odum (1971), Benson (1979), Diamond et al. (1987) and Judd (2002b). In 1852 stands of Texas palmetto (*Sabal mexicana*) extended along the Rio Grande from a point near its mouth to about 130 km inland from the Gulf of Mexico (Clover, 1937). However, by the late 1930s, clearing for agriculture had reduced the extent of this palm forest in the U.S.A. to a small reach of the Rio Grande from a point 16 km below Brownsville, Cameron County, Texas, upriver 6.4 km (Clover, 1937). The most extensive growth of palms was at Rabb Ranch, located approximately 16 km southeast of Brownsville at a bend where the river reaches its southernmost point (Clover, 1937; Davis, 1942). A 70 ha tract of the ranch was purchased by the Audubon Society in 1971 to establish the Sabal Palm Grove Sanctuary. Today about 13 ha of palm forest is present with the remaining land consisting of abandoned farm fields.

Clover (1937) included the Boscaje de la Palma as a coastal climax association of the Lower Rio Grande Valley of Texas. She pointed out that this is one of only four arborescent palm communities in the continental United States outside Florida, the other three being located in the southeastern Atlantic area, the Mississippi Delta area, and the southern California desert. Clover provided a list of 81 species associated with the Texas palmetto community. Davis (1942) focused on the Boscaje de la Palma in Cameron county, Texas, and she also provided a description of the distribution of Texas palmetto in the Rio Grande Delta area. Diamond et al. (1987) recognized the "Texas Palmetto Series" (dominated by *Sabal mexicana*) as a distinct late seral-stage forest in Texas, and they identified it as endangered. Indeed, it was one of only three communities (of 78) in Texas to be listed as endangered. The Texas Organization for Endangered Species (Carr et al., 1993) considers Texas palmetto a threatened species in the state.

Everitt et al. (1996) used remote sensing and spatial information technologies to map Texas palmetto in the Lower Rio Grande Valley of Texas. Future censuses may be compared with their map and imagery to quantify changes in population densities. The map also may prove useful to resource managers in identifying land for acquisition for conservation and reestablishment of Texas palmettos.

Land use and Climate Analysis

Land Use

The largest land-use parcel was agriculture (Table 3), followed by range-pasture and urban. Observations from the Brownville-Harlingen-McAllen sector of the LRGV show that the urban-residential category increased dramatically from 1960 to 1995 (Figs. 15 and 16). There was a slight decrease in agricultural land use. Overlays of 1995 and 1960 data show an explosive growth of residential urban parcels, particularly in the McAllen-Pharr-Edinburg area. Mapping of woodland shows very little of this category left in Hidalgo County. The year 2000 United States Census data for the four counties of the Lower Rio Grande Valley of Texas show a combined population approaching 1,000,000. The land use maps graphically indicate how this growth has impacted natural vegetation.

Table 3. Distribution of the major land use parcels, based on the 1995, Digital Orthophoto Quads (DOQ's).

Land Use	Percentage
Agriculture	53%
Range-pasture	18.5%
Residential	11.5%
Water	7.9%
Woodland	3.5%
Barren land	2.8%

Climate

The Lower Rio Grande Valley is classified as BSh (sub-tropical steppe) using the Köppen climate classification (Strahler and Strahler 2003:222-223). This is a semi-arid climate with generally warm conditions. Precipitation averages less than 700 mm.

annually, it is highly variable, and there are long periods of no rainfall, punctuated by brief, very wet cycles. Average annual temperatures are quite high at 23° C, frosts are quite rare, and the warm season quite long with daytime maximums of 35° C or greater quite common during June, July, and August. However, within the region, conditions are not homogeneous. There is significant variation in terms of both temperature and precipitation (Figs. 18 and 19). These variations are the result of the following factors: continental and marine effects, and heat islands. Climate maps for the Lower Rio Grande Valley were based on data from the National Climate Data Center, 1961-1990 normals (National Climatic Data Center 2003). The topics plotted include the following: mean annual temperature, January mean annual temperature, July mean annual temperature, average annual precipitation, September precipitation, cooling days, and heating days.

Temperature. The mean annual temperature isotherms shows a latitudinal component ranging from a low of 21.9° C in Port Mansfield to 23.4° C at McAllen. The January isotherms show both a marine and heat island influence. While there is a general trend for the isotherms to be warmer nearer the coast showing the marine influence, the highest temperatures are McAllen (14.7° C) and Brownsville (15.2° C). Summer temperatures are quite warm and show continental effects as one goes further inland where the mean temperatures increase. July, the warmest month, has the lowest means at the coast at 28.5° C, while the most distant stations inland, Roma and Rio Grande City, have the highest means at over 30° C. Daytime maximums in the western portion of the study area can be well over 40° C. This, combined with long periods of reduced, or no precipitation, can result in drought stress for vegetation. Cooling days refer to the combined total number of days and cumulative degrees when the daily mean is above 18.33° C and heating days refer to the cumulative total degrees below that number. In continental United States the Lower Rio Grande is near the highest of all recording stations in terms of cooling days and among the lowest in terms of heating days. The low deserts of southwestern Arizona and southeastern California would have higher cooling requirements, while Florida, south of Lake Okeechobee would have less heating days.

Precipitation. Variability is the defining characteristic of precipitation in the Lower Rio Grande Valley. There is a general decrease in annual precipitation from 700 mm. near the coast to 540 mm at Falcon Dam (Fig. 19). However, there is much variation from year to year and also within the region; one locality may receive 70 mm. of precipitation, while another, several km. distant may receive none. Within any given year, long periods of no precipitation may occur. September is the wettest month as this is when tropical systems are most active. The coastal regions receive more rainfall from this source than areas farther inland. Tropical systems provide the majority of the annual precipitation for the region; when they do not materialize a drought cycle may occur.

Remote Sensing

High-resolution hyperspectral data from two airborne sensors that were acquired on two occasions at several locations in the Lower Rio Grande Valley, Texas, were analyzed by CSR to evaluate their capabilities in defining riparian vegetation composition. In April 1999, CASI (compact airborne spectrographic imager) collected 17 bands of data over three sites in the Rio Grande Valley. The CASI instrument collects data in specified spectral ranges in the visible and near-infrared portions of the spectrum. In September 1999, high-resolution HYMAP data were acquired over three sites, including the Santa Ana National Wildlife Refuge. The HYMAP instrument collects 128 channels from 380 nm to 2,500 nm. Although the HYMAP collects more spectral information and is highly calibrated, it is substantially more expensive for data collection. Preliminary analysis of the two airborne, hyperspectral, data-imaging systems, which have similar spatial resolution (~ 4 m) but different spectral coverage, shows that riparian vegetation composition is better defined by the sensor that includes longer wavelength infrared bands (HYMAP).

Classification of Riparian Woodlands

Classification of woodland and riparian vegetation in the Lower Rio Grande Valley was completed by CSR using the most recent Landsat imagery that was acquired. To identify the riparian coverage in the Lower Rio Grande Valley, two Landsat ETM+ scenes were used to provide full data coverage from Falcon Dam to the mouth of the Rio Grande. The dates of the data used in the classification were June 12, 2001 for the east scene and March 15, 2001 for the western scene. A supervised maximum likelihood classifier was used to classify the riparian coverage. Training data were selected manually using a combination of vegetation surveys, digital orthophotography, and field data. The pixels identified as riparian forest were compared to the corresponding data acquired during the winter (February 23, 2002 and November 23, 2000). Areas mislabeled as riparian forest in the initial classification, such as crops, were removed from the final riparian forest result. In addition, trees labeled as riparian forest in residential areas were manually removed from the product for subsequent analysis. The data set was entered into the BEG GIS for analysis.

Riparian Distribution in the U.S. and Mexico.

To make comparisons between the remaining riparian vegetation in the U.S. (Texas) and Mexico, we created a 20-km wide buffer zone along the Rio Grande, with 10-km on the U.S. side and 10-km on the Mexico side (Fig. 20). Of the total area analyzed (526,936 ha), 49 % of the area is in the U. S. and 51 % is in Mexico. Of the total woodlands mapped within this area of analysis, 74 % is in the U. S., and 26 % is in Mexico. However, compared to other land cover, only small percentages of woodlands remain in the U.S. (6 %) and Mexico (2%).

If we assume that in the past, most of the area was vegetated with riparian woodlands and brushlands as has been suggested by some authors, then almost 95 % of these wooded areas have been cleared in the U.S., and 98 % in Mexico. On the U.S. side, this is in agreement with estimates by Jahrsdoerfer and Leslie (1988) who stated that since the early 1900's, 95 % of the native brushland has been cleared for agriculture, urban development, and recreation, and in riparian areas they estimated that 99 % of native brush has been destroyed. These percentages are in relatively close agreement with the 91 % loss of woodlands in Cameron County quantified by Tremblay and White (2002) for the period 1930's to mid-1980s.

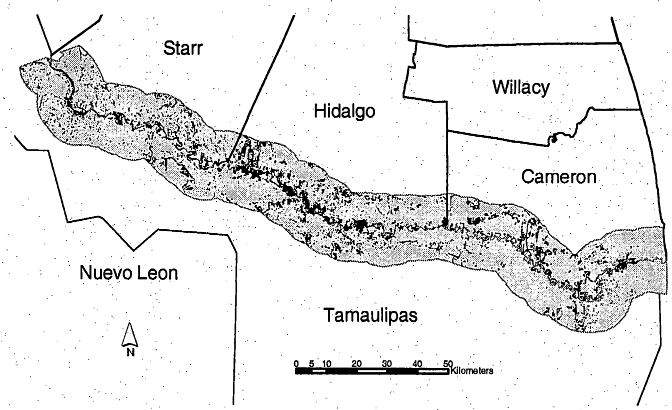

Figure 20. Illustration showing 20 km buffer zone along the Rio Grande from Gulf of Mexico to Falcon Dam. Black polygons represent woodland areas.

Using a more restricted area along the Rio Grande, a 3-km-wide corridor paralleling the river on the U.S. and Mexico sides, we had similar results in terms of percentages of riparian vegetation as those stated above in the 10-km-wide corridor. In the 3-km analysis, CSR analyzed and classified riparian vegetation using Landsat 7 TM data acquired in 1999 and 2000 for two scenes, east and west, that cover the entire study area. These corridors extend from Falcon Dam to the mouth of the Rio Grande. Results of the analysis indicate that ~ 5,890 ha of forested and scrub/shrub riparian vegetation occurs along the Rio Grande on the U.S. side, compared with ~ 1,840 ha in Mexico. The relative percentages in U.S. and Mexico are 76 and 24, respectively, which is the same as in the 10-km-wide corridors. The total area encompassed by these 3-km-wide corridors is ~ 93,000 ha on each side of the Rio Grande, indicating that only ~ 6% of the corridor in the U.S. contains riparian vegetation, and about 2% in Mexico.

Historical Loss of Riparian Vegetation on the U.S. Side of the Rio Grande

Since 1900, it has been estimated that 99% of the riparian vegetation adjacent to the Rio Grande has been removed (Jahrsdoerfer and Leslie, 1988). To gain a more quantitative understanding of historical distribution patterns of riparian vegetation and the location and magnitude of losses in the U.S., BEG digitized and analyzed woodlands as depicted on USGS topographic maps prepared in the early 1900's (1916 to 1936) in Cameron County. These maps were supplemented by interpreting and mapping woodland vegetation on historical aerial photographs to fill in gaps where topographic maps were not available. Results of the analysis indicate that in the mid-1930's ~ 81,887 ha of woodlands was in Cameron County. By the early to mid-1980's, only 7,337 ha of woodlands in this original area remained, indicating a loss of ~ 91% of this resource (Figure 21). Most of the loss occurred as a result of clearing for agricultural expansion and urban growth. The analysis of woodland vegetation mapped on these early topographic surveys provides information that allows a more quantitative evaluation of historical riparian distribution and change.

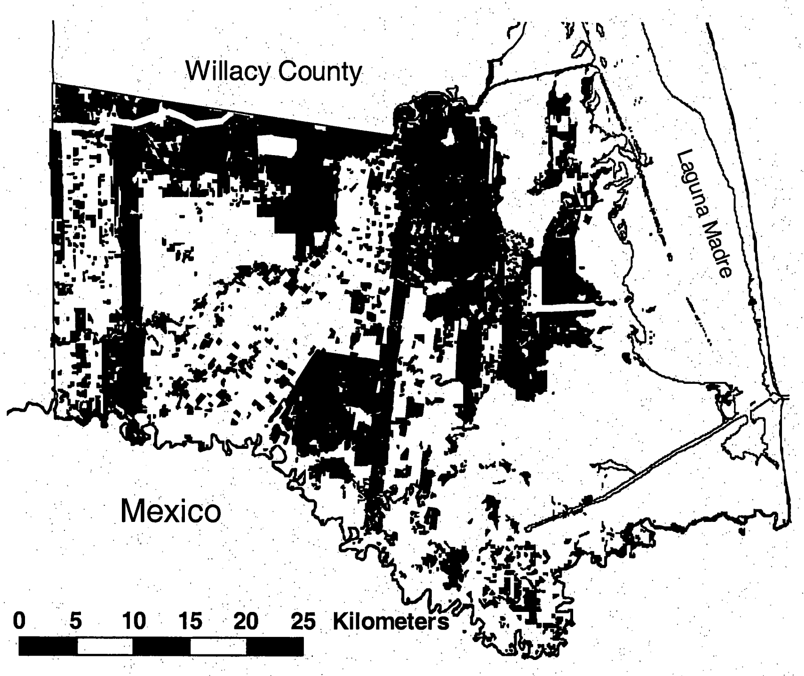

Figure 21. Map showing areas in which woodland vegetation in the 1930's was cleared by the 1980's in Cameron County, Texas. Cleared areas are shown in black.

Classification of Evergreen and Deciduous Vegetation Communities

The Center for Space Research analyzed high-resolution hyperspectral (HYMAP) and lower-resolution multispectral (Landsat TM) data along the Rio Grande Valley to refine our classification of woodlands and riparian vegetation. CIR photography with 1-m resolution was used in conjunction with field surveys and high-resolution (4 to 7 m) spectrally calibrated hyperspectral data in order for us to train classification algorithms and visually evaluate results in the Santa Ana National Wildlife Refuge. The refuge contains one of the largest contiguous riparian communities along the Rio Grande. The remote-sensing signatures at these training sites were also used for preliminary classification of medium-resolution Landsat 7 data in order for us to evaluate the utility of these sites in upward scaling and improving the riparian classification of Landsat 7 TM data. These data have extensive areal coverage but lower spatial resolution than that of hyperspectral data and DOQ's and lower spectral resolution than that of hyperspectral data.

Because of the large number of species representing riparian vegetation along the Rio Grande and the difficulty in adequately differentiating the various species using remotely sensed imagery, we established five classes of vegetation communities defined by the presence of evergreen and deciduous species and combinations of the two. The composition of the vegetation was determined from field surveys and interpretation of high-resolution, digital CIR aerial photographs (DOQ's) acquired during winter months.

This classification approach is modeled after the USFWS National Wetlands Inventory program, in which riparian vegetation inventory and mapping conventions were developed for the Western United States. The USFWS classification is hierarchical, with the Riparian System having two subsystems, lentic and lotic, subdivided into forested and scrub/shrub classes. These, in turn, have three subclasses—deciduous, evergreen, and mixed, from which we established five subclasses consisting of (1) evergreen; (2) deciduous; (3) mixed, co-dominant; (4) mixed, evergreen dominant; and (5) mixed, deciduous dominant. Examples of common evergreen species identified through field surveys in the Santa Ana National Wildlife Refuge and along other reaches of the Rio Grande include Texas ebony (*Chloroleucon ebano*) (Fig. 22), anacua (*Ehretia anacua*), granjeno (*Celtis pallida*), la coma (*Sideroxylon celastrina*), huisache (*Acacia minuata* (Fig. 23), and tepeguaje (*Leucaena pulverulenta*). Examples of deciduous species include hackberry (*Celtis laevigata*), cedar elm (*Ulmus crassifolia*), mesquite (*Prosopis glandulosa*), black willow (*Salix nigra*), retama (*Parkinsonia aculeata*), Texas persimmon (*Diospyros texana*), and Rio Grande ash (*Fraxinus berlandieriana*). This last species is deciduous, or semi-evergreen.

Riparian Vegetation Subclasses in the Lower Rio Grande Valley: Scaling Upward from the Santa Ana National Wildlife Refuge

High-resolution hyperspectral data from HYMAP, acquired of the Santa Ana National Wildlife Refuge, were analyzed with respect to (1) 27 ground-truth sites in which dominant vegetation had been determined, and (2) more than 40 training sites (Fig. 24) classified visually from large scale DOQ's. In addition, over 115 field sites outside of the refuge (Fig. 14) that had been examined to determine vegetation composition were used in conjunction with the DOQ's to select training sites on Landsat 7 imagery. The Rio Grande Valley is covered by two landsat scenes, east (path 26, row 42) and west (path 27, row 42) (Fig. 5). These scenes overlap in the Santa Ana NWR. Landsat 7 data include both summer and winter acquisitions. More than 10 iterations of the classification were completed in the analysis of Landsat 7 data in order to evaluate classification accuracy with respect to variations in training sites and variations in the season in which the imagery was acquired. Relatively good classification accuracies were achieved in scaling upward from DOQ's to the hyperspectral data in the refuge. Classes and spatial trends were relatively well defined (Fig. 25). Poorer results were achieved in scaling upward from hyperspectral data to Landsat 7 TM data (Fig. 26) and degraded further when extended beyond the refuge (Fig. 27). Although general trends in vegetation communities outside the refuge were defined, boundaries between classes were less distinct and there was a larger scattering of classes. Improved results were achieved by augmenting the training sites and updating parameter estimates. Field sites that were classified according to evergreen and deciduous plant composition are shown in Figure 28.

Training sites delineated on winter photographs (DOQ's) were applied to hyperspectral images, which were then classified. The resulting classification was used as baseline data against which to measure the accuracy of Landsat 7 classification results. Landsat imagery acquired in March and February consistently had better results for all classes

Figure 22. Photo of *Choroleucon ebano* (Texas ebony), an evergreen species in Bentsen State Park.

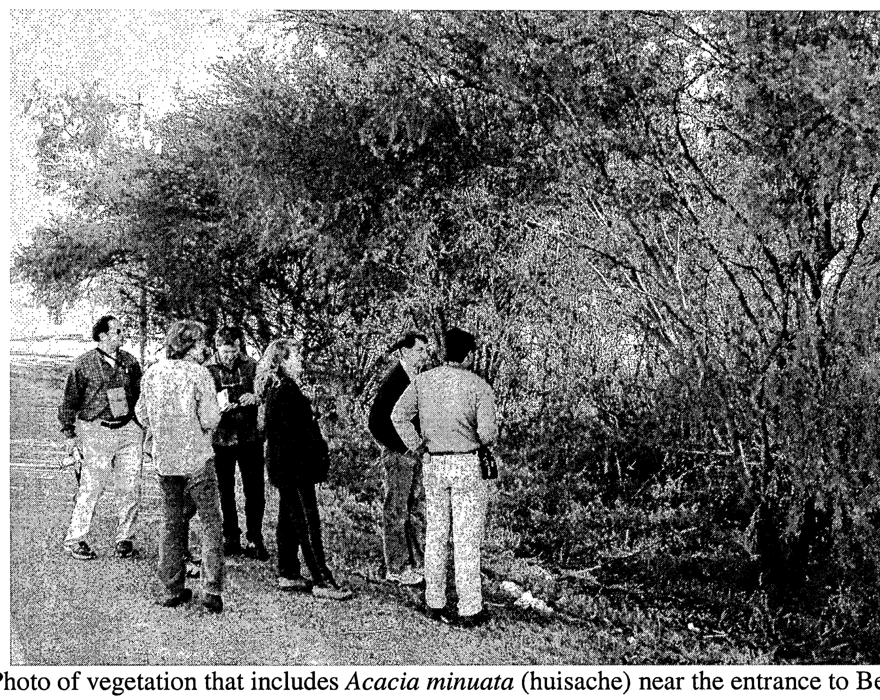

Figure 23. Photo of vegetation that includes *Acacia minuata* (huisache) near the entrance to Bentsen State Park. Photo taken in December, 2003, before leaf fall.

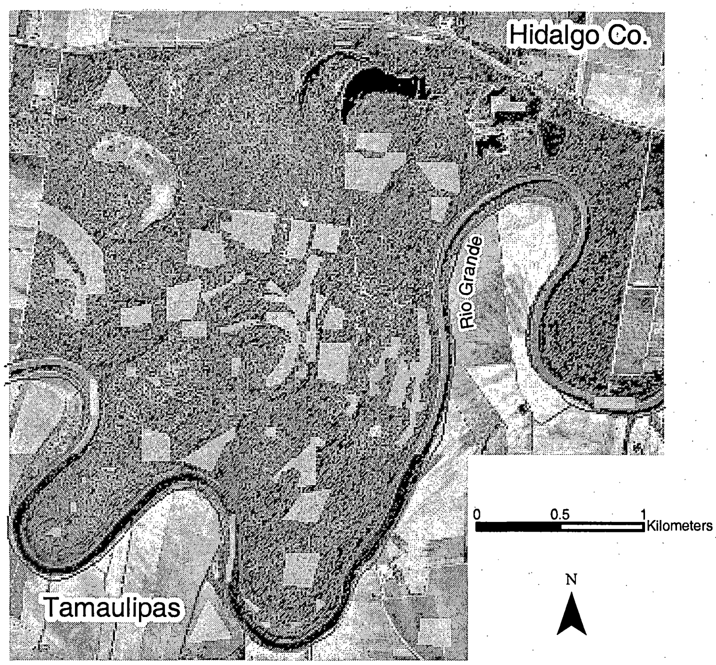

Figure 24. Computer training sites identified in Santa Ana National Wildlife Refuge based on winter 1995-1996 DOQs used for classification of Landsat 7 TM+ scenes.

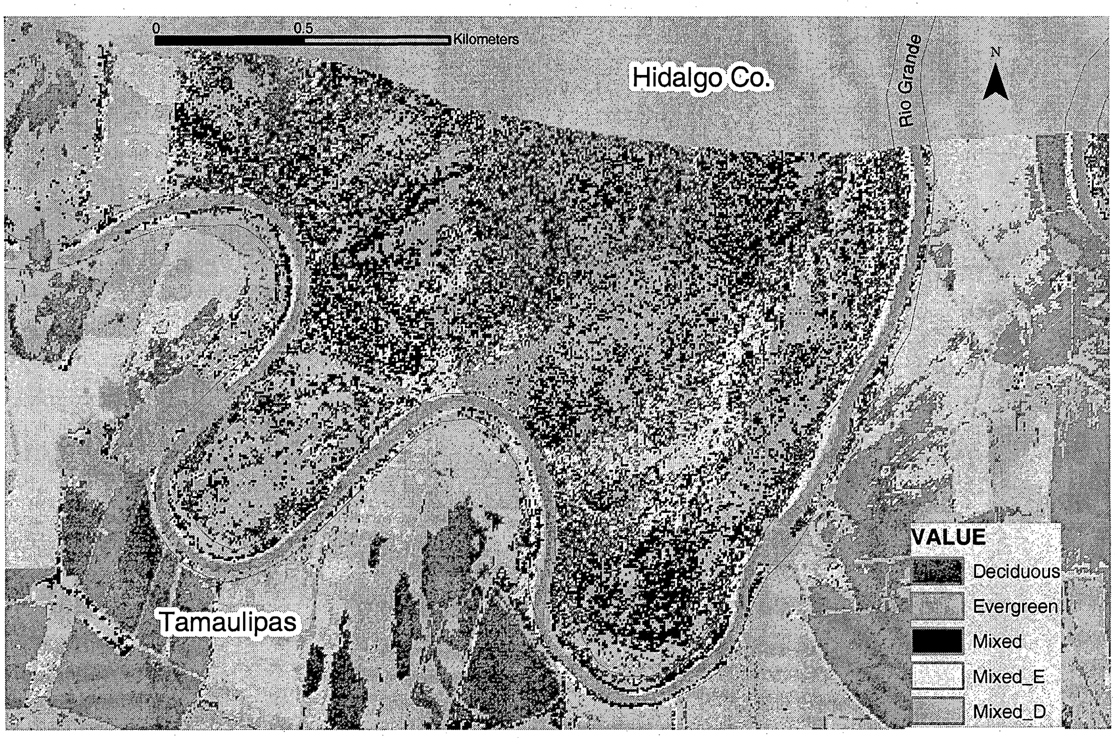

Figure 25. Classification of Hymap scene for southern half of Santa Ana National Wildlife Refuge.

Figure 26. Classification of Santa Ana National Wildlife Refuge portion of Summer 2000 Landsat 7 ETM+ scene using training sites identified both within the refuge and outside the refuge.

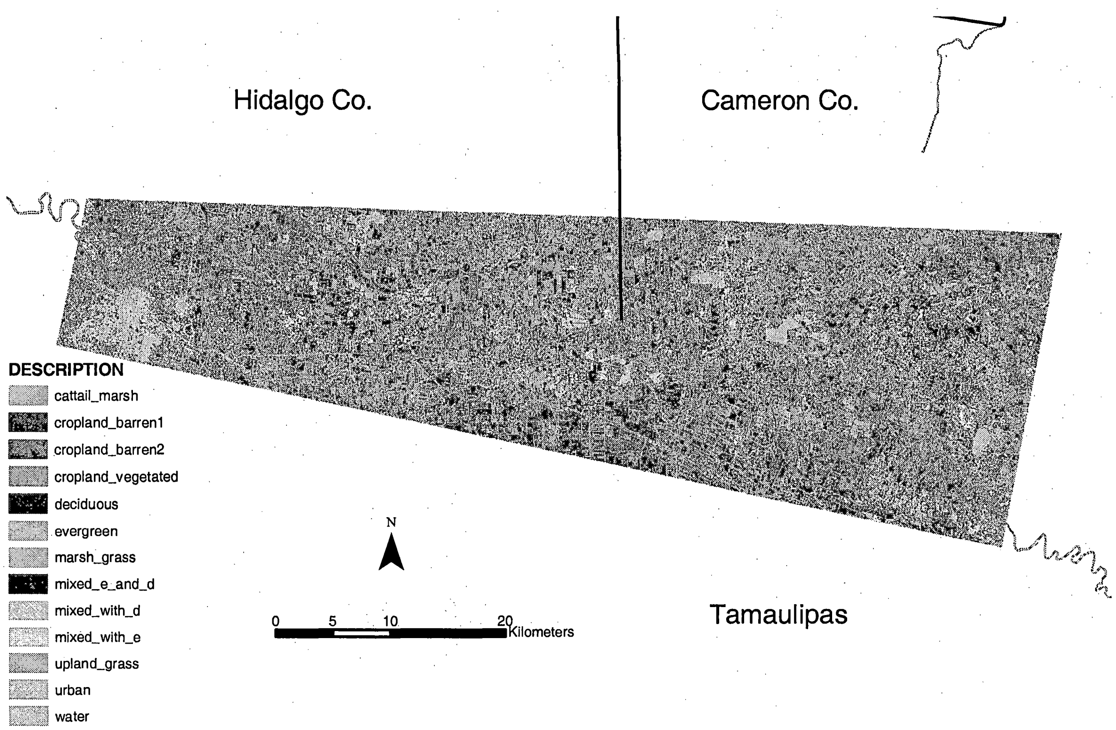

Figure 27. Classification of Winter 2002 Landsat 7 TM+ scene using training sites identified within Santa Ana National Wildlife Refuge and additional training sites outside Santa Ana.

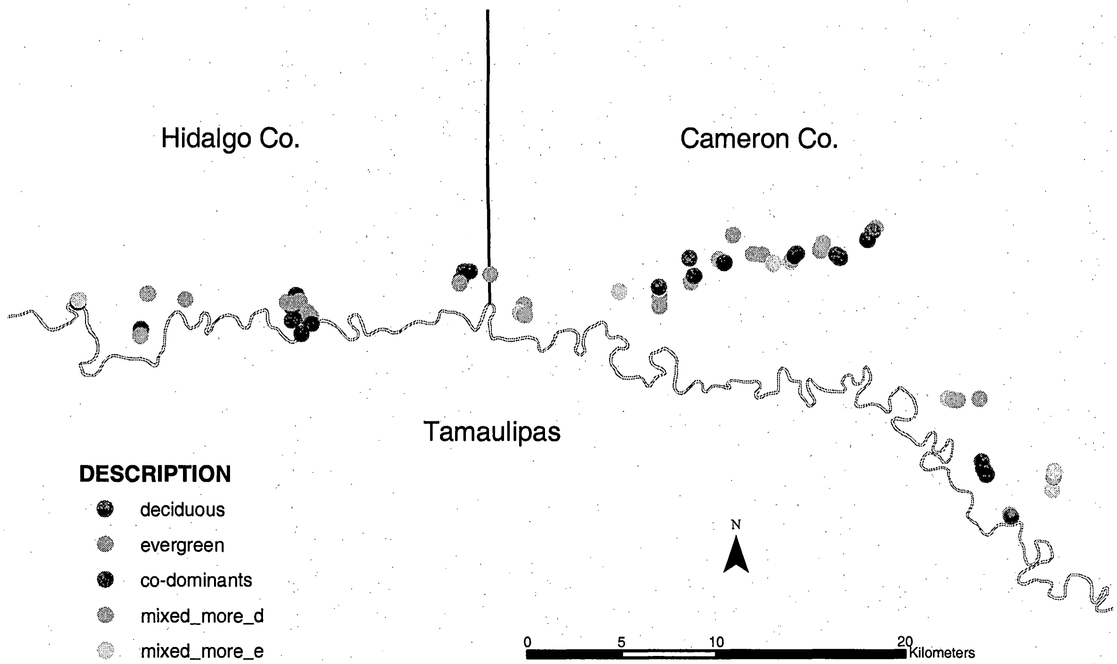

Figure 28. Locations at which vegetation communities were inventoried, and based on composition classified as evergreen, deciduous, or a combination of the two as shown in map legend.

compared to imagery acquired in June and October (Table 4). This was expected because of the higher spectral contrast between deciduous and evergreen vegetation during winter months when deciduous trees have dropped their leaves. Although the hyperspectral data were acquired on September 21, before deciduous vegetation leaf fall, the high resolution of these data, both spectrally and spatially, allowed a more complete and accurate classification of riparian vegetation than the lower resolution Landsat 7 data, and thus the HYMAP classification was used as our standard for comparison and upscaling.

In the southern half of the Santa Ana NWR (Fig. 25), the distributions of riparian classes based on HYMAP analysis, listed in descending order, are (1) mixed, with evergreen and deciduous co-dominant, followed by (2) deciduous dominant, (3) mixed, with deciduous dominant, (4) mixed, with evergreen dominant, and (5) evergreen dominant (Table 4). Comparison of HYMAP classes with classes delineated using Landsat 7 TM data show that February Landsat classification results are in closest agreement with that from HYMAP (Table 4). Next, in terms of overall agreement, is the classification of March Landsat 7 data. The best classification results were achieved with Landsat data acquired during winter months and the poorest with that acquired during summer months (Figs. 29 and 30).

Table 4. Distribution of riparian classes, in percentage of total riparian area, as mapped using HYMAP and Landset 7 data.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	(%)	(%)	(%)	(%)	(%)
Mixed e & d	29	29	28	9	22
Deciduous (d)	23	23	20	8	16
Mixed, d dominant	19	22	10	19	9
Mixed, e dominant	19	17	21	30	14
Evergreen (e)	11	8	21	34	39

Similar results were achieved through GIS overlay analysis. For most classes, the winter scenes (February and March) had a higher percentage of spatial coincidence with Hymap classes than did the summer scenes. Still, even the winter scenes had percentages of coincidence that were relatively low with a maximum of 31 percent for the mixed e & d class. The April scene had the highest coincidence for evergreen at 45 percent, but areas of non coincidence for evergreen were also higher. Classification of large areas as evergreen in the April scene may be the result of bright green, spring foliage on trees and shrubs, which created a spectral reflectance similar to evergreen species.

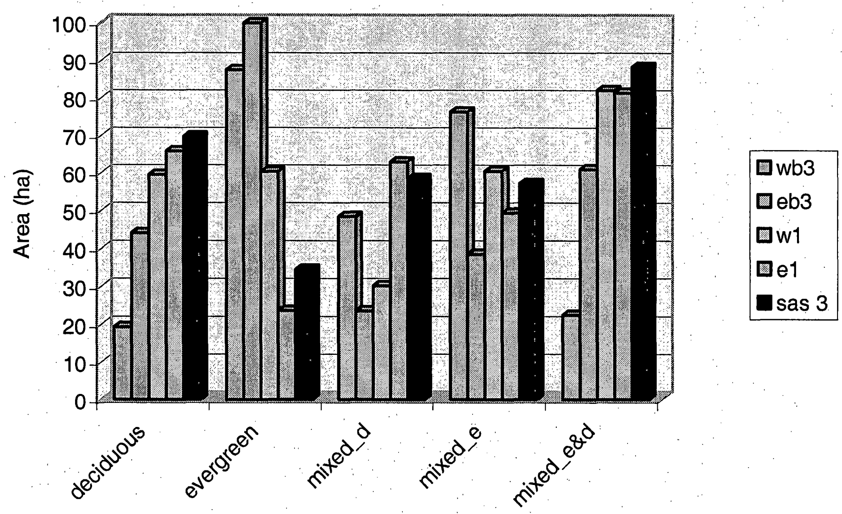

Figure 29.Comparison of areas (ha) of riparian vegetation composition in the southern half of Santa Ana NWR based on classifications of HYMAP (sas 3), summer LS-7 scenes (wb3 west and eb3 east), and winter LS-7 scenes (w1 west and e1 east). Note that areas mapped in the winter scenes are overall closer in area for each class than the summer LS-7 scenes.

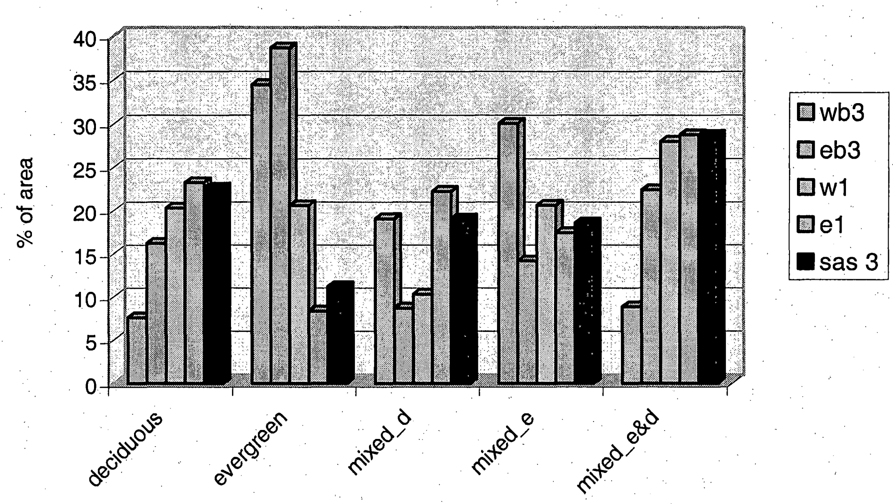

Figure 30. Comparison of percentage area of riparian vegetation composition in the southern half of Santa Ana NWR based on classifications of Hymap (sas 3), summer LS-7 scenes (wb3 west and eb3 east), and winter LS-7 scenes (w1 west and e1 east). Classes mapped using the winter LS-7 scenes are generally closer in percentage to the HYMAP (sas 3) class percentages than the classes mapped using the summer LS-7 scenes.

We continued to refine our classification of riparian vegetation communities into five classes defined by the presence of evergreen and deciduous species and combinations of the two. Training sites for hyperspectral and multispectral analysis of Bentsen-Rio Grande Valley State Park were determined based on visible analysis and interpretation of high-resolution, digital CIR aerial photographs (DOQ's) acquired during winter months, and high-resolution hyperspectral data from HYMAP (Fig.3). Laser altimetry data acquired of Bentsen-Rio Grande Valley State Park (Fig. 31) provided additional information for classifying land cover. Field work was conducted in mid December to ground truth classified communities and training sites in and around Bentsen-Rio Grande Valley State Park.

Based on all of our analysis, primarily of the Santa Ana NWR, we concluded that the best results in the evergreen and deciduous characterization were obtained using only three subclasses -- evergreen, deciduous, and mixed -- as defined by the USFWS. Five subclasses, as discussed above, could not be as consistently classified because of complex mixtures in vegetation communities.

Modeling of Riparian Vegetation through Overlay Analysis

Among our most powerful tools were the interpretative capabilities of GIS technology to examine linkages between riparian ecology and various parameters such as vegetation composition and distribution, soil relationships, and land use. These kinds of data help determine the temporal and spatial distribution of riparian habitats, and the factors that maintain them or adversely impact them. Newly acquired hyperspectral data from HYMAP and multispectral data from Landsat 7 were analyzed. Results were entered into our GIS for overlay analysis with other completed GIS layers.

Riparian-Vegetation Characteristics Model

A preliminary overlay analysis in the Cameron County portion of the study was performed to test the riparian-vegetation characteristics model. The model incorporates three parameters and their associations with riparian vegetation. Geology (Fig. 6), FEMA flood areas (Fig. 10), and soil-drainage capacity layers were processed in a weighted overlay-analysis model within the GIS environment. Two parameters are required to perform the weighted overlay analysis. Within the individual layer each classification was assigned a suitability level. For this model, the suitability level was determined through a qualitative comparison with mapped riparian locations and a nonrigorous statistical modeling of the riparian locations relative to the data layer. Alluvial floodplain deposits captured from the McAllen-Brownsville Geologic Atlas of Texas sheet were assigned a suitability level of 2, whereas all other geologic units were considered to be less suitable and were assigned a value of 1. Flood areas mapped by FEMA as "no flood" zones were given the higher suitability value of 2. Cameron County soils, which are classified as "well drained" in the Natural Resources Conservation Service SSURGO database, were assigned the higher suitability. Soils with other drainage capacities were considered to be less suitable and assigned a value of 1.

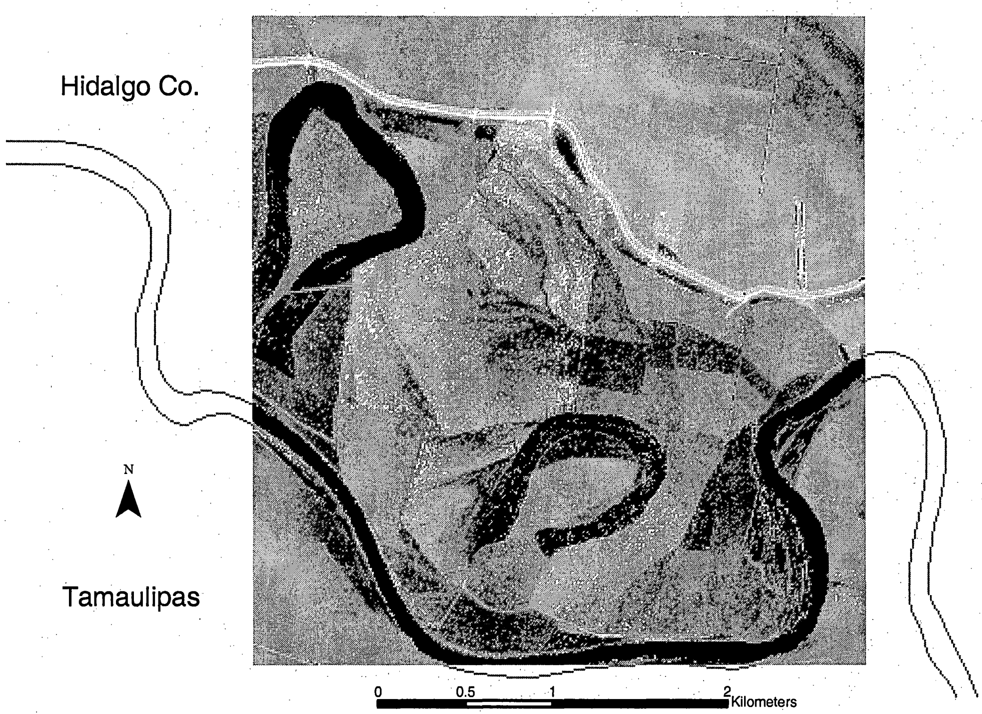

Figure 31. Image of 3 meter ground resolution of the minimum height LIDAR data for Bentsen State Park.

The second parameter required to perform a weighted overlay is a calculation of the relative amount of influence contributed by each model layer. For testing purposes, this more subjective component of the model is negated if an equal influence percentage is assigned to all layers. Model results reflect the addition of assigned suitability between each layer in the weighted overlay process. Areas with conforming higher suitability accumulate a higher overall cell value. The parameters entered into this weighted overlay model are "weighted" only in the sense that suitability levels reflect some degree of preference for riparian vegetation. Future models can incorporate, with a higher level of objectivity, the relative influence between data layers.

This preliminary model isolated a total area of almost 67,000 ha, defined on the basis of alluvial floodplain deposits, well-drained soils, and the absence of flooding. These parameters, or layers, had a mildly to moderately predictive relationship with forested and scrub/shrub vegetation that had been classified from remote-sensing data (Landsat 7). This relationship suggests that the defined area may have been the site of extensive riparian vegetation in the past. Using our historical analysis of woodland vegetation in Cameron County in the 1930's (Fig. 21), we found that almost 43,000 ha of woodlands, potentially riparian vegetation, was present within this defined area. Within the area today, only 4,617 ha of forested and scrub/shrub vegetation remains, suggesting a possible 90% loss.

Soil and Riparian Vegetation Relationships

There is a strong correlation between riparian vegetation and soils (based on the Natural Resources Conservation Service SSURGO database, Fig. 9). Along the Rio Grande in Cameron County, for instance, although 17 different soils were associated with riparian vegetation, 3 soils made up more than 60% of the association (Rio Grande silt loam—22%; Zalla loamy fine sand—21%, and Matamoros silty clay—18%). Within a 3-km-wide corridor along the Rio Grande, which includes Cameron, Hidalgo, and Starr Counties, we found a similarly strong relationship. Within the 3-km corridor, these three soils plus Laredo silty clay loam cover only 32% of the area, but they are the soils on which 61% of the riparian vegetation occurs.

This relationship with soils, when correlated with other parameters, such as topography, hydrology, vegetation composition, and land use, is useful in analyzing riparian vegetation with respect to historical trends, anthropogenic effects, and optimal sites for reestablishment of riparian tracts.

To investigate, further, the relationship between soils and riparian vegetation, we analyzed the distribution of more common species of trees and shrubs that were identified at the approximately 160 field sites visited by researchers from UT-PanAm. All shrub and tree species identified at the sites were entered into our GIS, and a GIS layer of the common species found at the sites was developed for analysis of soil relationships. Most riparian species were more commonly associated with soil textures of silty clay loam and silt rather than clay (Fig. 32). Analysis of specific soils support this in that most species were more common on two soils, Laredo Silty Clay Loam and the Rio Grande Silt Loam; there were fewer occurrences on clays such as the Grulla Clay and Harlingen Clay (Table 5 and Figs. 33-39).

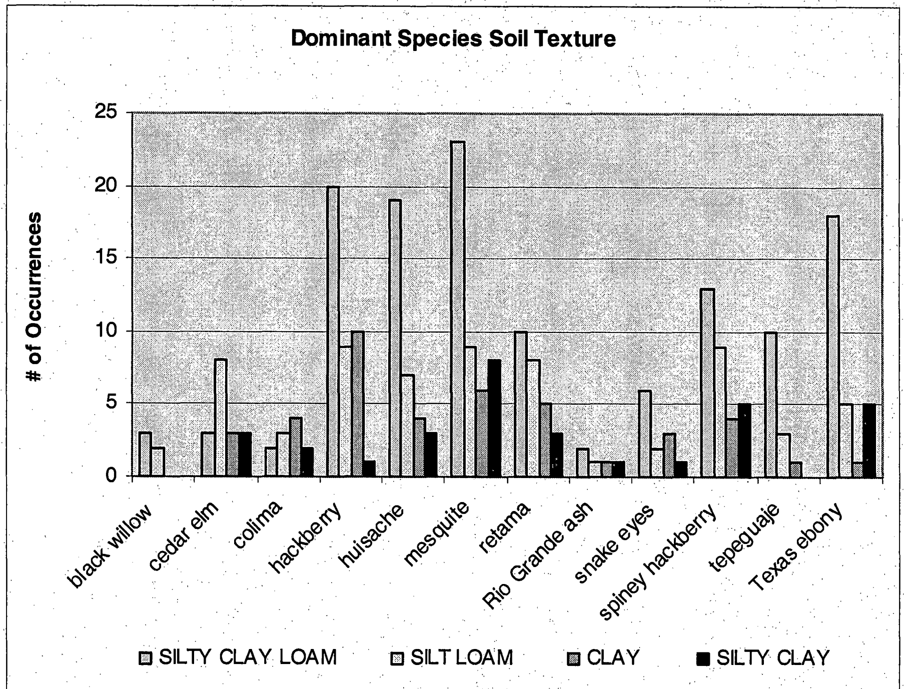

Figure 32. Relationship between plant species and sediment texture.

Table 5. Frequency (number of occurrences) of common riparian tree and shrub species on four soils in the Lower Rio Grande Valley.

	[illegible]	[illegible]	[illegible]	[illegible]
Acacia minuata (Huisache)	9	6	2	2
Celtis laevigata (Sugar hackberry)	15	8	7	2
Celtis pallida (Granjeno)	7		4	
Chloroleucon ebano (Texas ebony)	15	4		1
Leucaena pulverulenta (Tepeguaje)	7	3	1	
Parkinsonia aculeata (Retama)	6	7	3	2
Phaulothamnus spinescens (Snake Eyes)	5	1	1	2
Prosopis glandulosa (Mesquite)	14	6	3	3
Salix nigra (Black willow)	2	2		
Ulmus crassifolia (Cedar elm)	1	6	3	
Zanthoxylum fagara (Colima)	2	2	4	
Total occurrences	83	45	28	12

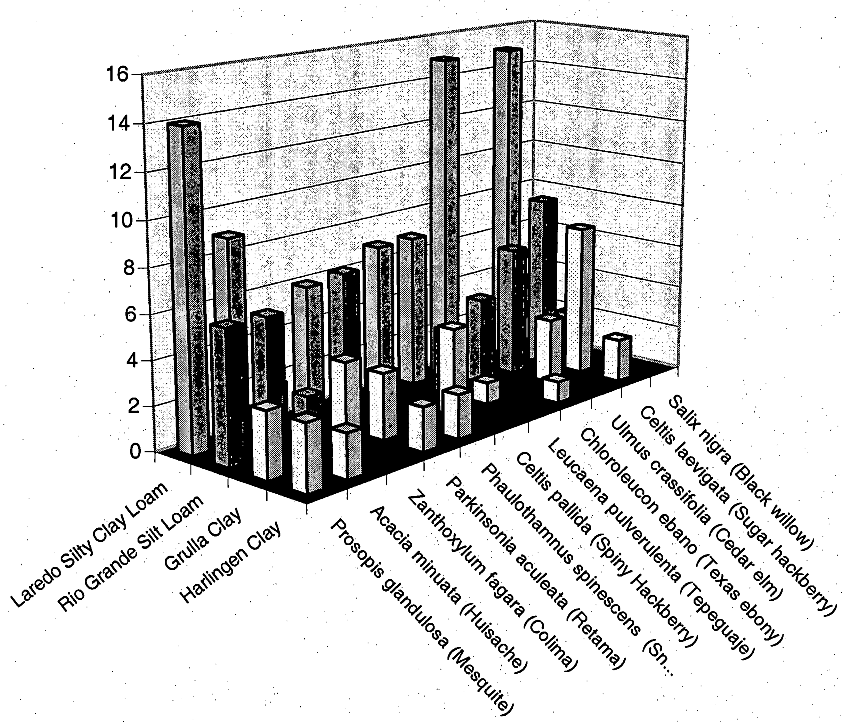

Figure 33. Illustration (based on Table 6) showing the relationship (number of occurrences) between common riparian species and four common soils in the Lower Rio Grande Valley.

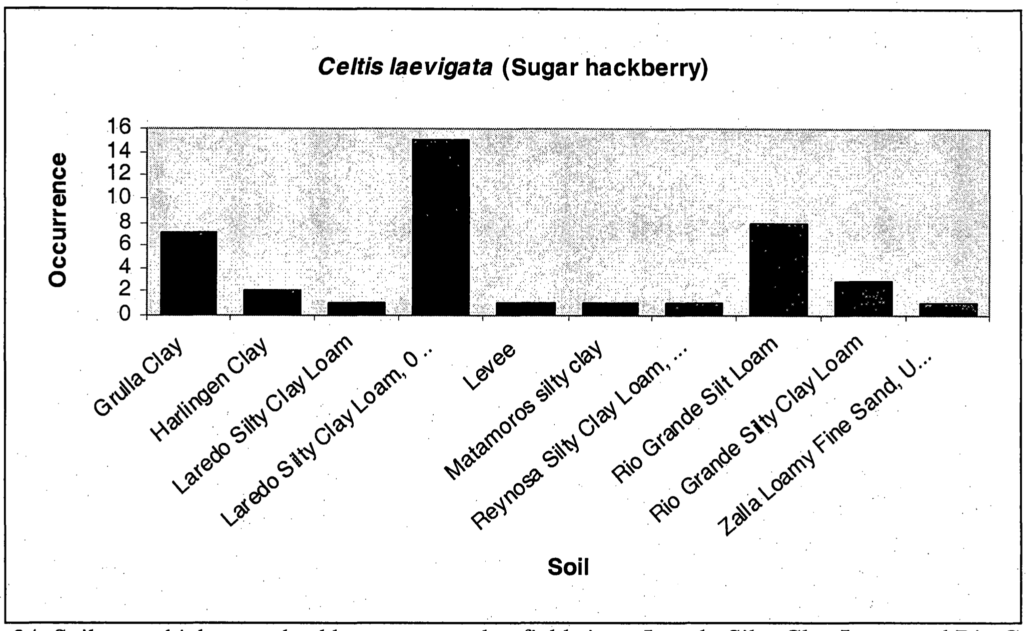

Figure 34. Soils on which sugar hackberry occurred at field sites. Laredo Silty Clay Loam and Rio Grande Silty Clay Loam were the dominant soils on which it was found.

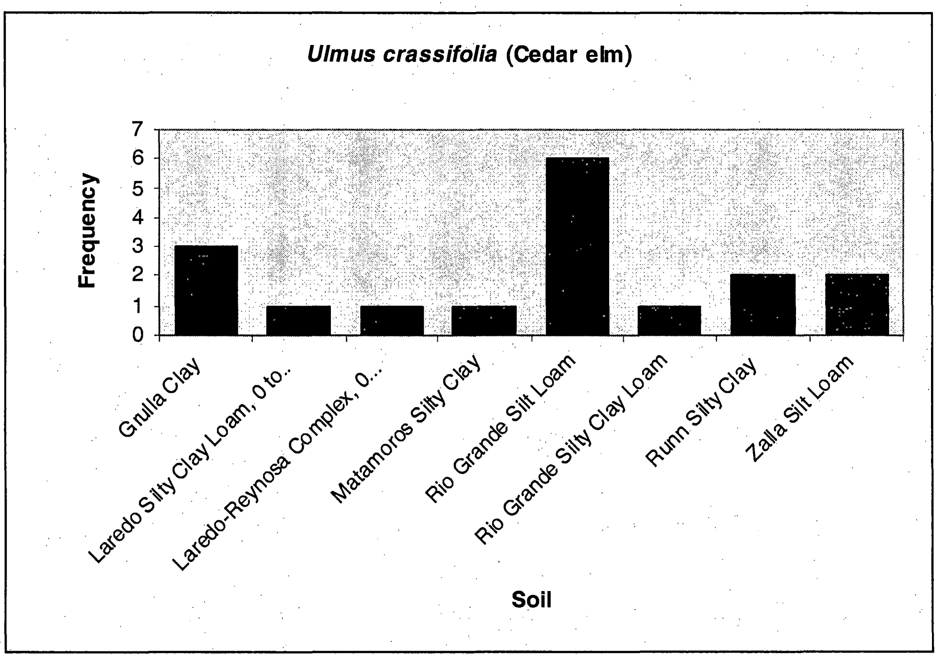

Figure 35. Soils on which Cedar Elm occurred at field sites. Rio Grande Silt Loam was the dominant soil on which this species occurred.

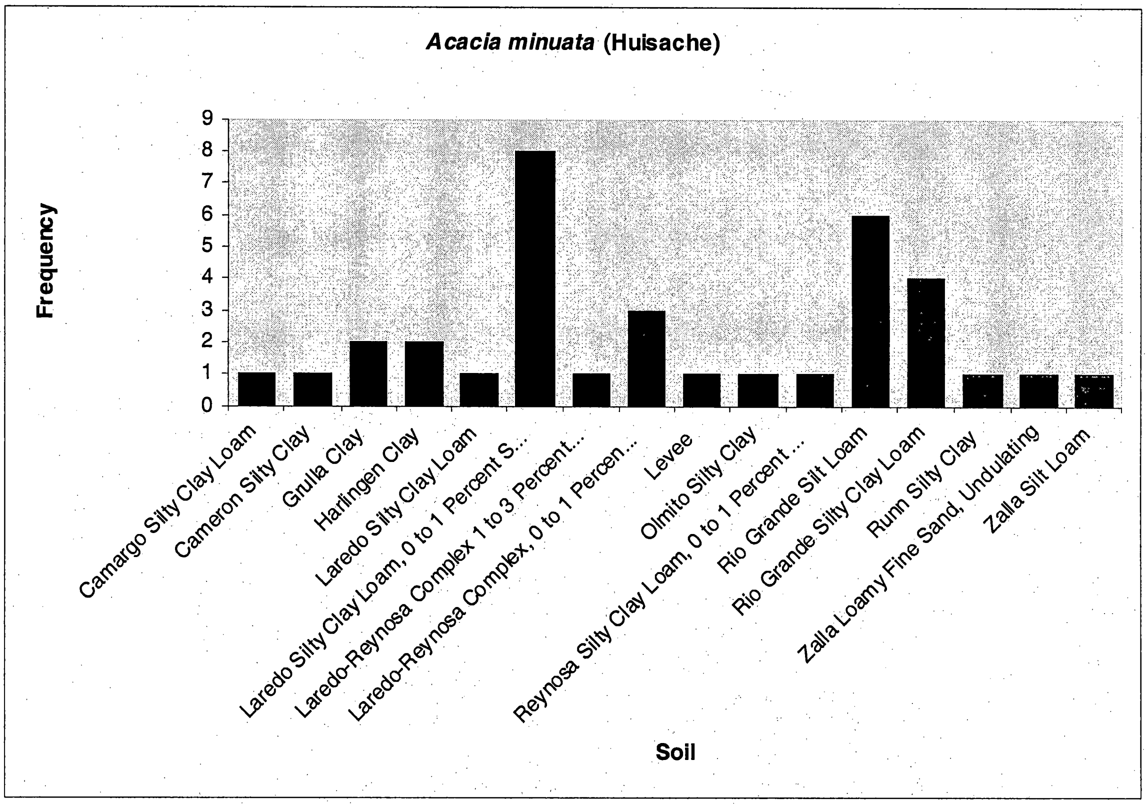

Figure 36. Soils on which Huisache occurred at field sites. Laredo Silty Clay Loam and Rio Grande Silt Loam were the dominant soils on which it was found.

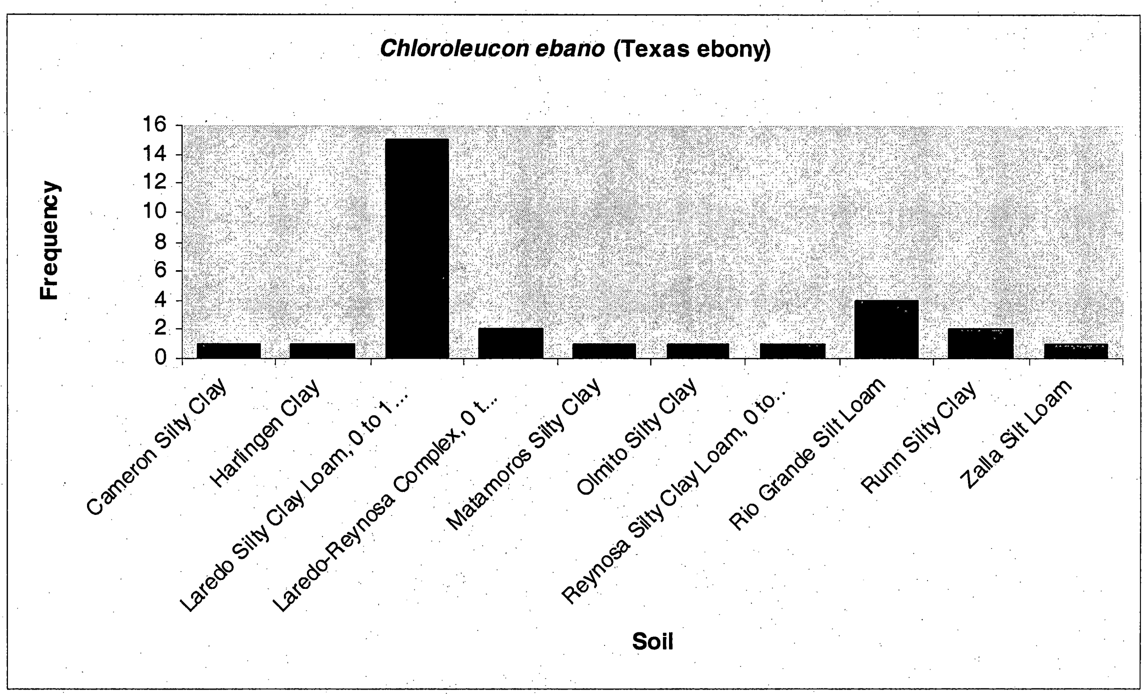

Figure 37 . Soils on which Texas Ebony occurred at field sites. Laredo Silty Clay Loam and Rio Grande Silt Loam were the dominant soils on which Texas Ebony was found.

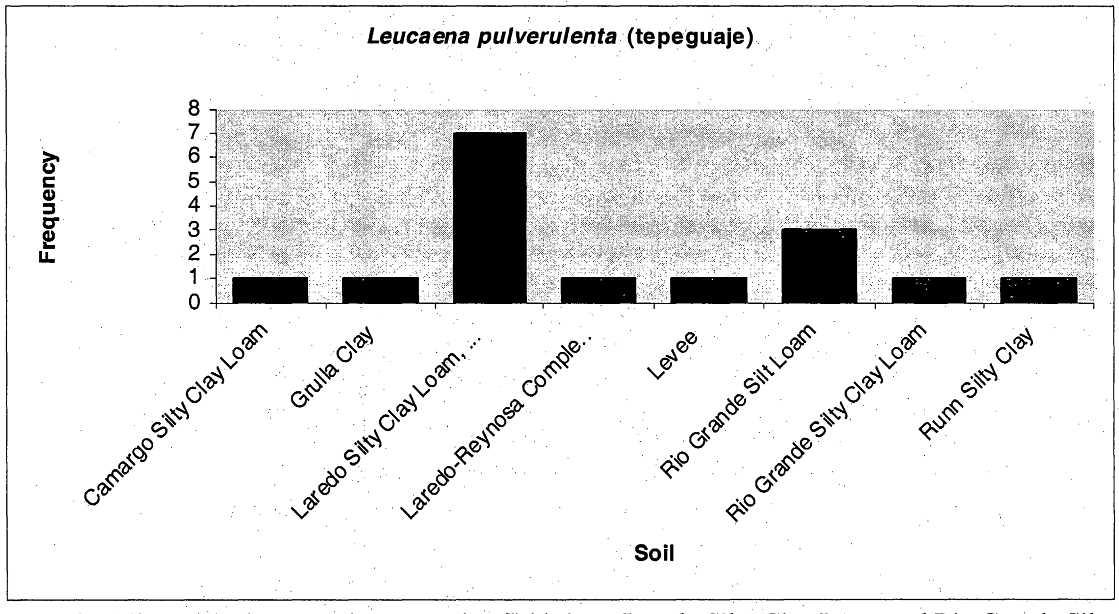

Figure 38. Soils on which tepeguaje occurred at field sites. Laredo Silty Clay Loam and Rio Grande Silty Clay Loam were the dominant soils on which it was found.

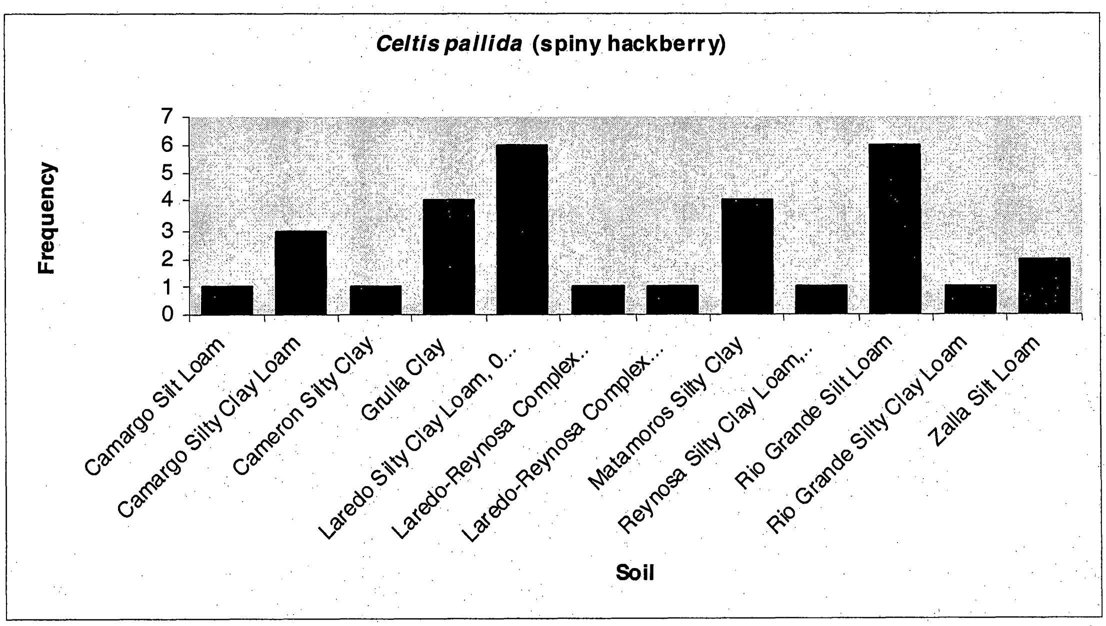

Figure 39. Soils on which spiny hackberry occurred at field sites. Laredo Silty Clay Loam, Rio Grande Silty Clay Loam, Matamoros Silty Clay, and Grulla Clay were the dominant soils on which it was found.

Soil Salinities and Vegetation Distribution

Salinity is a significant issue in the Rio Grande Valley, where problems arise for two primary reasons: (1) poor drainage combined with high evaporation, (2) salt water intrusion from Laguna Madre. Natural vegetation distribution reflects effects of salinization and drainage (hydrology and soils). Trees such as Texas ebony and Sabal palm used to be more abundant along the Rio Grande banks and resaca courses (Richardson, 1995). Where salinities are higher, canopies are lower and vegetation dominated by salt tolerant shrubs and some mesquite. High salinity in soils, runoff, and shallow ground water effects riparian vegetation, changing ecosystem variables and classification structure over time. These data can be identified from local data and linked with remote data. It is important to consider this along side the hydrology because some of these changes are water-quantity related.

Using salinity (conductivity) data from soil measurements by USDA, we analyzed the relationship between soil salinities and 10 common species of shrubs and trees (Fig. 40). This was accomplished by analyzing the number of occurrences of the trees and shrubs on soils with salinities (based on conductivity) ranging from 0 to 4 millimhos/cm.

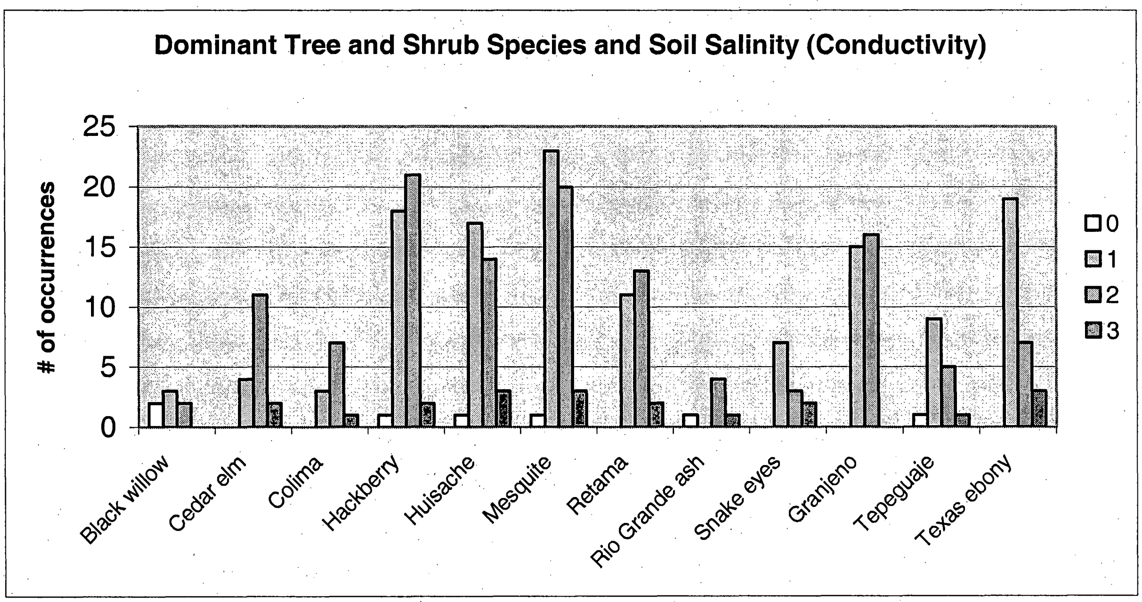

Figure 40. Number of occurrences of common trees and shrubs on soils with salinites (based on conductivity) ranging from 0 to 4 millimhos/cm. Includes all species found at distinct field check sites and transect locations as reported by Lonard and Judd, 2002. Soil salinity represented as electrical conductivity in millimhos per centimeter at 25 degrees C. Electrical conductivity is a measure of the concentration of water-soluble salts in soils The Natural Resource Conservation Service classifies soils as either nonsaline (0-2) or slightly saline (2-4).

This analysis was based on all species found at distinct field check sites and transect locations as reported by Lonard and Judd, 2002. The Natural Resource Conservation Service classifies soils as either nonsaline (0-2) or slightly saline (2-4). Among the results was that *Prosopis glandulosa* (mesquite) occurred more frequently in slightly saline soils than other species. This is in agreement with Lonard and Judd (2002), who found mesquite to be the dominant species near the coast where the effects of salinity and salt spray are most pronounced and inland where precipitation is less (Figs. 41 and 43).

SUMMARY AND CONCLUSIONS

Riparian ecosystems of the southwestern United States are among the most productive ecosystems of North America. The rapid decline of these ecosystems throughout the United States has made riparian conservation a focal issue. Analysis and classification of riparian vegetation in the Lower Rio Grande Valley using remote sensing data supported by field surveys confirmed what other researchers have qualitatively suggested, which is that riparian vegetation has been greatly diminished since the early 1900's. Digital analysis of historical maps and aerial photographs of woodland distribution in Cameron County as part of this project indicated that in the mid-1930's there were ~ 81,887 ha of woodlands in Cameron County. By the early to mid-1980's, only 7,337 ha of woodlands in this original area remained, indicating a loss of ~ 91% of this resource. This quantitative assessment of woodland loss helps confirm the earlier qualitative estimates of up to 95 % loss.

By comparing the distribution and amount of riparian vegetation within a 20 km corridor along the Rio Grande (10 km in the U.S. and 10 in Mexico), we found that of the total woodlands mapped within this area of analysis, 74 % occurs in the U. S., and 26 % occurs in Mexico. However, compared to other types of land cover such as cropland, only small percentages of woodlands, 6 % in the U.S. and 2 % in Mexico, remain. If we assume that in the past, most of the area was vegetated with riparian woodlands and brushlands as has been suggested by some authors, then almost 95 % of these wooded areas have been cleared in the U.S., and 98 % in Mexico. On the U.S. side, this is in agreement with estimates by Jahrsdoerfer and Leslie (1988) who stated that since the early 1900's, 95 % of the native brushland has been cleared for agriculture, urban development, and recreation, and in riparian areas they estimated that 99 % of native brush has been destroyed.

Based on repeated vegetation surveys, reseachers at UT-PanAm concluded that the dominant trees and shrubs along the Rio Grande appeared to be replacing themselves. In addition, they found that there were no trees at the mouth of the river and the vegetation there was similar to that found along the Laguna Madre shore of barrier islands. Mesquite (*Prosopis glandulosa*) was the dominant tree near the coast, where soil salinity and wind-blown salt spray are greatest, and it was also dominant in the western section of the river near Falcon Dam, where rainfall is least and where the Rio Grande floodplain is narrow. Sugar hackberry (*Celtis laevigata*) was the dominant tree species at all other sites except at Santa Ana National Wildlife Refuge, where cedar elm (*Ulmus crassifolia*) and anacua (*Ehretia anaqua*) were the dominant trees. Granjeno (*Celtis pallida*) was a dominant shrub throughout the riparian corridor. The introduced Guinea grass (*Panicum maximum*) and buffel grass (*Pennisetum ciliare*) were the dominant species in the ground cover, displacing native species.

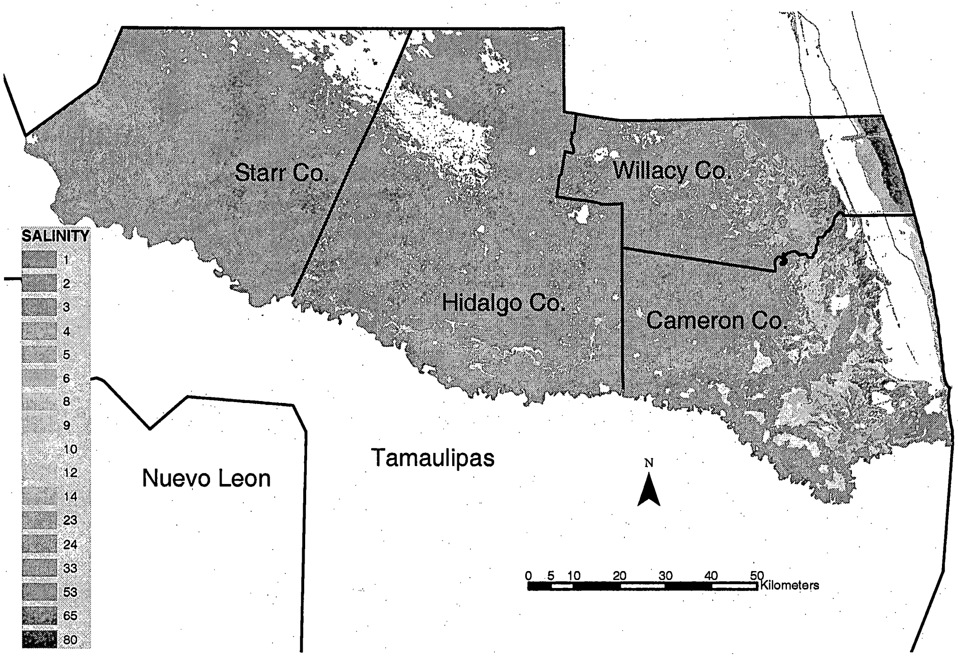

Figure 41. Soil salinity measured as electrical conductivity. Salinity decreases away from the Gulf of Mexico. Units are millimhos per centimeter. Derived from NRCS, SSURGO database.

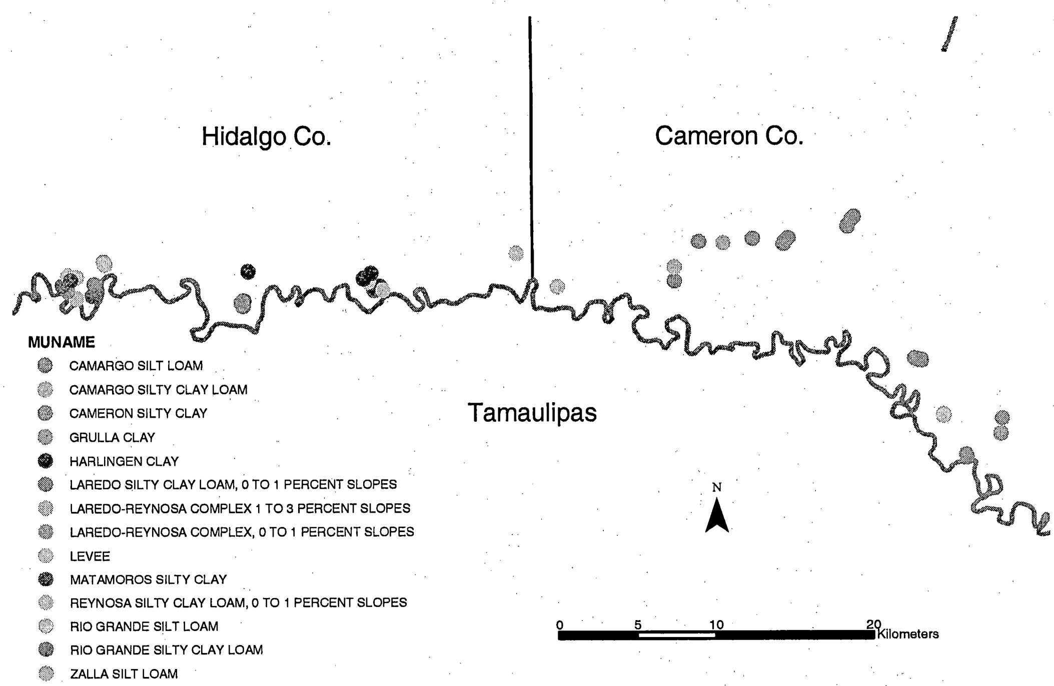

Figure 42. Soils associated with field site locations where Mesquite was reported. Derived from (NRCS) SSURGO database.

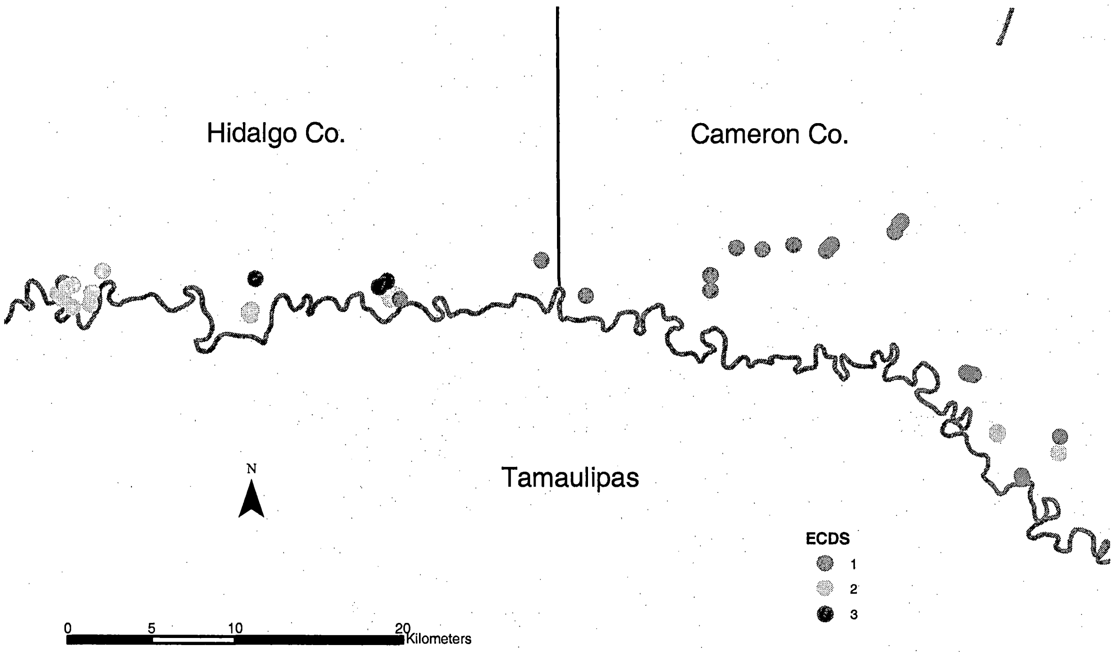

Figure 43. Soil salinity (conductivity) distribution at field site locations where Mesquite was reported. Units are millimhos per centimeter. Derived from U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Soil Survey Geographic (SSURGO) database.

The present riparian communities may be greatly influenced by human interventions such as construction of dams that have eliminated annual flooding of the Rio Grande. Blair (1950) reported that cedar elm (*Ulmus crassifolia*) was the dominant tree in the floodplain of the Rio Grande in the Lower Rio Grande Valley of Texas. We found cedar elm was a dominant species only at Santa Ana NWR (Lonard and Judd, 2002). This species' distribution and abundance may have been adversely affected by the curtailment of annual flooding of the Rio Grande. Certainly, it is no longer a widespread dominant species in the riparian zone of the lower reach of the Rio Grande.

There is a strong correlation between riparian vegetation and soils. Along the Rio Grande in Cameron County, for instance, although 17 different soils were associated with riparian vegetation, 3 soils made up more than 60% of the association (Rio Grande silt loam—22%; Zalla loamy fine sand—21%, and Matamoros silty clay—18%). Within a 3-km-wide corridor along the Rio Grande, which includes Cameron, Hidalgo, and Starr Counties, we found a similarly strong relationship. Within the 3-km corridor, these three soils plus Laredo silty clay loam cover only 32% of the area, but they are the soils on which 61% of the riparian vegetation occurs. This relationship with soils, when correlated with other parameters, such as topography, hydrology, vegetation composition, and land use, is useful in analyzing riparian vegetation with respect to historical trends, anthropogenic effects, and optimal sites for reestablishment of riparian tracts.

Among the positive aspects regarding riparian vegetation along the Lower Rio Grande Valley are the efforts of the U.S. Fish and Wildlife Service, the Texas Parks and Wildlife Department, and National Audubon Society. These agencies have been involved in programs that actively help preserve and restore riparian habitats ranging from the TPWD's acquisition of white-winged dove habitat, to the National Audubon Society's Sabal Palms Santuary, and the USFWS large-scale acquisitions as part of the USFWS LRGV National Wildlife Refuge (Fig. 44). Associated with the acquisition of land is a rigorous planting program in which a variety of evergreen and deciduous shrubs and trees are being planted to help restore riparian habitat corridors along the Rio Grande. It is hoped that the analysis of riparian distribution and dominant plant species identified and reported in this study and their relationship to soils, hydrology, land use, salinity, topography, and other parameters will assist in riparian restoration programs in the Lower Rio Grande Valley, and serve as a foundation for future analysis of riparian floodplain communities by linking local and remotely sensed regional data using GIS.

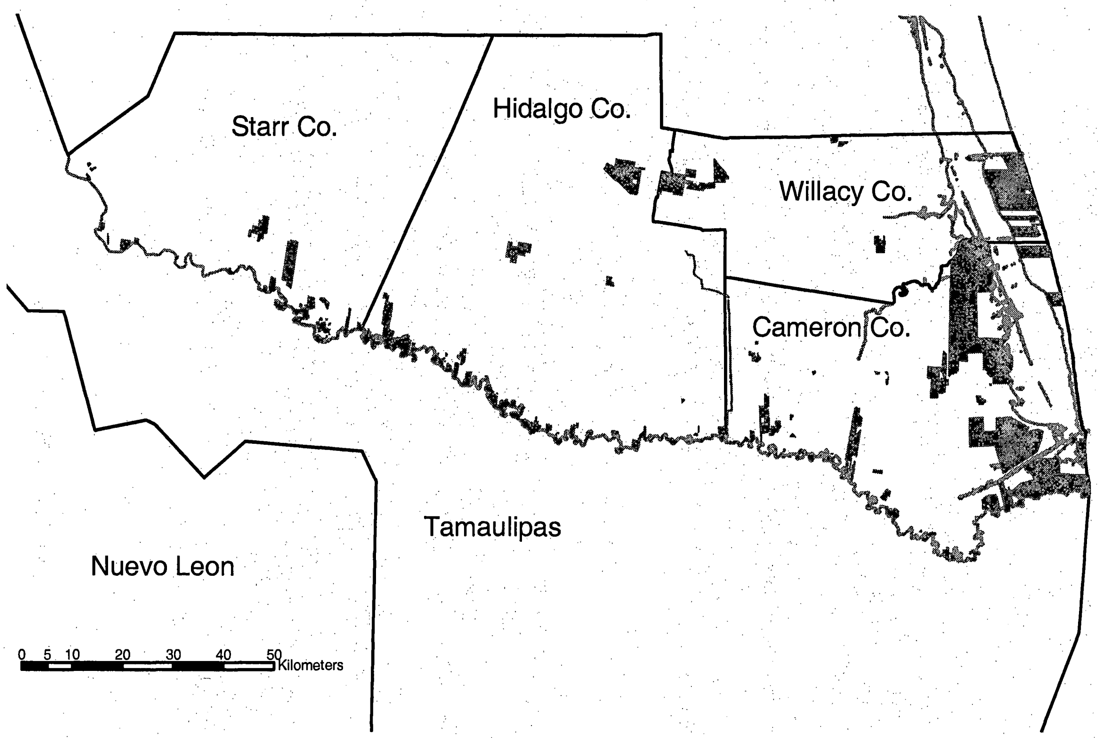

Figure 44. Map showing areas acquired by the U.S. Fish and Wildlife Service as part of the Lower Rio Grande Valley National Wildlife Refuge.

ACKNOWLEDGMENTS AND DISCLAIMERS

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The authors would like to thank Cris Best and Mitch Sternberg with the USFWS for providing information on land acquired as part of the Lower Rio Grande National Wildlife Refuge program.

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Lonard, R. I., and F. W. Judd. 2002. Riparian vegetation of the lower Rio Grande: *Southwestern Naturalist* 47(3):420-432.

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PUBLICATIONS AND PRESENTATIONS
(Directly or partly associated with the project)

Articles

Lonard, R. I. and F.W. Judd. 2002. Riparian vegetation of the Lower Rio Grande: The Southwestern Naturalist, 47 (3):420-432.

A related paper was published as a chapter in a book co-edited by Judd. It contains general information about the vegetation of southern Texas, including the Rio Grande riparian corridor. The citation is:

Judd, F. W. 2002. Tamaulipan Biotic Province, pp.38-58, in The Laguna Madre of Texas and Tamaulipas, J. W. Tunnell, Jr., and F. W. Judd (eds.), Texas A&M University Press, College Station, Texas, 346 pp..

Tremblay, T. A., White, W. A., and Raney, J. A., In preparation, Mid-20th century woodlands loss in Cameron County, Texas: The Southwestern Naturalist.

Lonard, R. I., Judd, F. W., Everitt, J. H., Escobar, D. E., Davis, M. R., Crawford, M. M., and Desai, M. D., in press, Riparian Vegetation at the Mouth of the Rio Grande: Proceedings of the 18th Biennial Workshop on Color Photography and Videography in Resource Assessment, University of Massachusetts-Amherst, 16–18 May 2001.

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Presentations

Upward scaling in remote sensing and classification of riparian vegetation, Lower Rio Grande Valley, Texas, Melba Crawford (presenter), Bill White, Tatiana Encheva, Tom Tremblay, Jay Raney, Frank Judd, Bob Lonard, and Gene Paull, presented October 2002, EPA Upscaling Workshop.

Frank Judd, "Riparian Vegetation of the Lower Rio Grande," presented at the Rio Grande Symposium of the 105th annual meeting of the Texas Academy of Science, February 28-March 2, 2002, at Texas A&M International University, Laredo, Texas.

Thomas Tremblay and William White, "Historical Distribution and Loss of Woodlands in the Lower Rio Grande Valley, " presented at the Rio Grande Symposium of the 105th annual meeting of the Texas Academy of Science, February 28-March 2, 2002, at Texas A&M International University, Laredo, Texas, p. 57.

Findings of the University of Texas at Brownsville in relation to this land use study were presented at two conferences:

March 1, 2002, 105th Annual Meeting of the Texas Academy of Sciences, Laredo, Texas - Land Use Mapping in the Lower Rio Grande Valley of Texas, 1960-1995

April 12, 2002, 36th Annual Meeting of The Geological Society of America, South-Central Section, Alpine, Texas. Land Use in the Lower Rio Grande Valley of Texas.

Appendix 1. Ground truth sites

Ground Truth Sites
Rio Grande Delta of Texas

Site 1a - Lion Lake, Progresso. *Celtis laevigata* (Sugar hackberry) is dominant. Several large mesquites (*Prosopis glandulosa*) are present. Also present are anacua (*Ehretia anacua*), huisache (*Acacia minuata*), and chinaberry (*Melia azedarach*). Site is riparian, but disturbed.

Site 1b - Lion Lake, Progresso. A mixture of mesquites (*Prosopis glandulosa*), retama (*Parkinsonia aculeata*), tenaza (*Chloroleucon pallens*) and *Acacia greggii* (catclaw). *Phaulothamnus spinescens* (snake-eyes), and *Randia rhagocarpa* (crucillo) are common shrubs. Guineagrass (*Panicum maximum*) forms the ground layer. Site is riparian, but disturbed.

Site 1c - Lion Lake, Progresso. Mostly residences at this site. Anacua (*Ehretia anacua*) and four planted live oaks (*Quercus virginiana*). Site is riparian, but disturbed.

Site 1d - Lion Lake, Progresso. Ebony (*Chloroleucon ebano*) is dominant at this site. Also present is sugar hackberry (*Celtis laevigata*), huisache (*Acacia minuata*), lotebush (*Ziziphus obtusifolia*) and brazil (*Condalia hookeri*). Site is riparian, but disturbed.

Site 1e - Lion Lake, Progresso. A mixture of huisache (*Acacia minuata*), coma (*Sideroxylon celastrina*), retama (*Parkinsonia aculeata*), lotebush (*Ziziphus obtusifolia*), mesquite (*Prosopis glandulosa*), and granjeno (*Celtis pallida*). Guineagrass (*Panicum maximum*) forms the ground layer. Site is riparian, but disturbed.

Site 1f - Moon Lake, Progresso. A mixture of mesquite (*Prosopis glandulosa*), anacua (*Ehretia anacua*), sugar hackberry (*Celtis laevigata*), granjeno (*Celtis pallida*), and retama (*Parkinsonia aculeata*). Guineagrass (*Panicum maximum*) forms the ground cover. Site is riparian, but disturbed.

Site 1g - Moon Lake, Progresso. Mesquite (*Prosopis glandulosa*) is dominant at this site. Also present are huisache (*Acacia minuata*), retama (*Parkinsonia aculeata*), brazil (*Condalia hookeri*), lotebush (*Ziziphus obtusifolia*), and brush-holly (*Xylosma flexuosa*). Site is riparian, but disturbed.

Site 1h - Moon Lake, Progresso. Mesquite (*Prosopis glandulosa*) is dominant at this site. Also present are brazil (*Condalia hookeri*), coma (*Sideroxylon celastrina*), granjeno (*Celtis pallida*), and lotebush (*Ziziphus obtusifolia*). There is one large ebony (*Chloroleucon ebano*) right at the corner of the intersection. Site is riparian, but disturbed.

Site 1i - Moon Lake, Progresso. Mesquite (*Prosopis glandulosa*) is dominant at this site. Also present are brazil (*Condalia hookeri*), retama (*Parkinsonia aculeata*), granjeno (*Celtis pallida*), and coma (*Sideroxylon celastrina*). Site is riparian, but disturbed.

Site 1j - Moon Lake, Progresso. A mixture of Mexican ash (*Fraxinus berlandieriana*), chinaberry (*Melia azedarach*), and popinac (*Leucaena leucocephala*). Site is riparian, but disturbed.

Site 1k - Moon Lake, Progresso. A mixture of brazil (*Condalia hookeri*), lotebush (*Ziziphus obtusifolia*), mesquite (*Prosopis glandulosa*), and huisache (*Acacia minuata*). Site is riparian, but disturbed.

Site 1l - Moon Lake, Progresso. Sugar hackberry (*Celtis laevigata*) is dominant here. There is one large date palm (*Phoenix canariensis*) at the site. Site is riparian, but disturbed.

Site 1m - Moon Lake, Progresso. This site has sugar hackberry (*Celtis laevigata*) and retama (*Parkinsonia aculeata*). Peppervine (*Ampelopsis arborea*), a climbing vine, covers trees at this site. This vine will be green year-round. Site is riparian, but disturbed.

Site 1n - Progresso. This site is upriver from the bridge at Progresso. On the lower terrace, nearest the river, the tree species include black willow (*Salix nigra*), sandbar willow (*Salix exigua*), zarza (*Mimosa pigra*), jara (*Baccharis salicifolia*), jara dulce (*Baccharis negelecta*), and huisache (*Acacia minuata*). On the second terrace (higher terrace) sugar hackberry (*Celtis laevigata*) is a strong dominant. Some retama (*Parkinsonia aculeata*) is present. Site is riparian.

Site 1o - Progresso. This site is near the pump station that takes water from the Rio Grande and moves it into Moon lake and Lion Lake. On the terrace closest to the river the species include sugar hackberry (*Celtis laevigata*), sandbar willow (*Salix exigua*), jara (*Baccharis salicifolia*), huisache (*Acacia minuata*), and saltcedar (*Tamarix aphylla*). There is a lot of peppervine (*Ampelopsis arborea*) covering the trees. Site is riparian.

Site ?- Moon Lake, Progresso. At a point at the southeast end of Moon Lake between Sites 1i and 1j there is a sizeable grove of fan palms (*Washingtonia robusta*). This site may show in the imagery. Site is riparian in location, but disturbed.

Site 2a - Run. Mesquite (*Prosopis glandulosa*) is abundant and the dominant in the tree and shrub layers. Also present in the shrub layer is snake-eyes (*Phaulothamnus spinescens*), chapotillo (*Amyris texana*), and lotebush (*Ziziphus obtusifolia*). Ground cover is totally guineagrass (*Panicum maximum*). Site is not riparian. It apprears to have been cleared in the past.

Site 2b - Run. We couldn't get to this site because of wet field roads. Will do later when fields are dry.

Site 2c - Run. Cedar elm (*Ulmus crassifolia*) is dominant here. Some of the trees are 15 m tall. Ebony (*Chloroleucon ebano*) is second in importance. One Mexican ash (*Fraxinus berlandieriana*). Shrubs present include coma (*Sideroxylon celastrina*), chapote (*Diospyros texana*), colima (*Zanthoxylum fagara*), chapatillo (*Amyris texana*) and brush-holly (*Xylosma flexuosa*). The site is riparian.

Site 2d - Run. Road wet in lower part of field and we could not get to this site. We will try again after it has dried.

Site 2e - Run, McManus Wildlife Management Area. Northeast corner of tract. Mesquite (*Prosopis glandulosa*) is dominant here. We have detailed information on this site based on ten 10m x 10m quadrats. We will send as a separate file. The site is riparian.

Site 2f - Run, McManus Wildlife Management Area. Mixture of large tepeguaje (*Leucaena pulverulanta*), mesquite (*Prosopis glandulosa*), sugar hackberry (*Celtis laevigata*), cedar elm (*Ulmus crassifolia*), huisache (*Acacia minuata*), and anacua (*Ehretia anacua*). Shrubs include brush-holly (*Xylosma flexuosa*) and barbados cherry(*Malphigia glabra*). The site is riparian.

Site 3a - West of Run. This is a revegetated site. Trees have been planted in rows running east to west. The ground cover is guineagrass (*Panicum maximum*). Trees present are up to 4 or 5 m tall. They include tepeguaje (*Leucaena pulverulenta*) as the dominant with smaller amounts of huisache (*Acacia minuata*), ebony (*Chloroleucon ebano*), anacua (*Ehretia anacua*) and cedar elm (*Ulmus crassifolia*). This site is riparian.

Site 3b - West of Run. Adjacent to the Rio Grande. Sugar hackberry (*Celtis laevigata*) is dominant. (*Salix exigua*) sandbar willow is right at river's edge. Also present is Mexican ash(*Fraxinus berlandieriana*), huisache (*Acacia minuata*), and granjeno (*Celtis pallida*). The site is riparian.

Site 4a - West of Santa Maria. Sugar hackberry (*Celtis laevigata*) and huisache (*Acacia minuata*) are dominants. Site is riparian.

Site 4b - West of Santa Maria. Mixture of species, no clear dominant. Mesquite (*Prosopis glandulosa*), retama (*Parkinsonia aculeata*), sugar hackberry (*Celtis laevigata*), huisache (*Acacia minuata*), saltcedar (*Tamarix aphylla*), chinaberry (*Melia azedarach*) and fan palm (*Washingtonia robusta*). Site is riparian.

Site 4c - West of Santa Maria. Sugar hackberry (*Celtis laevigata*) is dominant. Huisache (*Acacia minuata*) and retama (*Parkinsonia aculeata*) also are present. The site is riparian.

Site 4d - West of Santa Maria. Sugar hackberry (*Celtis laevigata*) is dominant. Also present are retama (*Parkinsonia acueata*) and huisache (*Acacia minuata*). The site is riparian

Site 4e - West of Santa Maria. Behind locked gate of IBWC. Will walk to later.

Site 4f - West of Santa Maria. Behind locked gate of IBWC. Will walk to later.

Site 4g - West of Santa Maria. Black willow (*Salix nigra*) is the dominant. Trees are up to 8 m in height. Mexican ash (*Fraxinus berlandieriana*) also present. Peppervine (*Ampelopsis arborea*) covers many trees. The site is riparian.

Site 4h - West of Santa Maria. Sugar hackberry (*Celtis laevigata*) is dominant. Huisache (*Acacia minuata*) is present. Trees are covered with peppervine (*Ampelopsis arborea*). Site is riparian.

Site 5a - Anacua Wildlife Management Area. This site has been planted. Trees are clearly in rows. Huisache (*Acacia minuata*) is dominant. Some ebony (*Chloroleucon ebano*), retama (*Parkinsonia aculeata*), jara dulce (*Baccharis neglecta*) are present. Also a few small sugar hackberry (*Celtis laevigata*) present. Site is riparian.

Site 5b - Anacua Wildlife Management Area. This site has been planted. Trees are in rows. The dominant is huisache (*Acacia minuata*). Smaller amount of ebony (*Chloroleucon ebano*) is present. Site is riparian.

Site 5c - Anacua Wildlife Management Area. Huisache (*Acacia minuata*) is dominant. Tepeguaje (*Leucaena pulverulenta*), retama (*Parkinsonia aculeata*), and mesquite (*Prosopis glandulosa*) are present. Site is riparian.

Site 5d - Anacua Wildlife Management Area. This site is not part of the Anacua WMA. There is a residence here. Ebony (*Chloroleucon ebano*) is dominant. Also present are anacua (*Ehretia anacua*), tenaza (*Chloroleucon pallens*), brazil (*Condalia hookeri*), chapote (*Diospyros texana*), granjeno (*Celtis pallida*), cedar elm (*Ulmus crassifolia*) and coma (*Sideroxylon celastrina*). The site is riparian.

Site 6a - West of Las Rusias. Tepeguaje (*Leucaena pulverulenta*) is dominant. Trees are up to 15 m tall. Sandbar willow (*Salix exigua*) is present. A mantle of vines including possum-grape (*Cissus incisa*), serjania (*Serjania brachycarpa*), and old man's beard (*Clematis drummondii*) form a mantle covering trees. The site is riparian.

Site 6b - West of Las Rusias. There are about equal amounts of sugar hackberry (*Celtis laevigata*), tepeguaje (*Leucaena pulverulenta*), and ebony (*Chloroleucon ebano*). The site is riparian.

Site 6c - West of Las Rusias. There is a mixture of mesquite (*Prosopis glandulosa*), huisache (*Acacia minuata*), granjeno (*Celtis pallida*), and brazil (*Condalia hookeri*). We cound not discern a dominant. The site is riparian.

Site 6d - West of Las Rusias. Ebony (*Chloroleucon ebano*) is dominant. There is a fair amount of tepeguaje (*Leucaena pulverulenta*). The vegetation appears planted. The site is riparian.

Site 6e - West of Las Rusias. Ebony (*Chloroleucon ebano*) is dominant. Also present are huisache (*Acacia minuata*), mesquite (*Prosopis glandulosa*), and tepeguaje (*Leucaena pulverulenta*). The site is riparian.

Site 6f - North of Las Rusias. Tepeguaje (*Leucaena pulverulenta*) is dominant. Ebony (*Chloroleucon ebano*) is fairly abundant. Huisache (*Acacia minuata*) and popinac (*Leucaena leucocephala*) close to the road. Vegetation appears to have been planted. Site is riparian.

Site 6g - North of Las Rusias. Sugar hackberry (*Celtis laevigata*) is dominant. Also present is sandbar willow (*Salix exigua*). The site is riparian

Site 6h - North of Las Rusias. Mesquite (*Prosopis glandulosa*) and ebony (*Chloroleucon ebano*) are co-dominants. Also present are huisache (*Acacia minuata*), tepeguaje (*Leucaena pulverulenta*), retama (*Parkinsonia aculeata*), lotebush (*Ziziphus obtusifolia*) and jara dulce (*Baccharis neglecta*). Buffel grass (*Pennisetum ciliare*) and guineagrass (*Panicum maximum*) comprise the ground cover. The site is riparian.

Site 7a - Rangerville. Sugar hackberry (*Celtis laevigata*) is dominant. Quite a lot of ebony (*Chloroleucon ebano*) and retama (*Parkinsonia aculeata*). Guineagrass (*Panicum maximum*) forms a solid cover on the ground. The site is riparian.

Site 7b - Rangerville. Mesquite (*Prosopis glandulosa*) is dominant. Huisache (*Acacia minuata*) and tepeguaje (*Leucaena pulverulenta*) are present. Guineagrass (*Panicum maximum*) forms the ground cover. The site is riparian.

Site 7c - Rangerville. Large black willow (*Salix nigra*) are dominant. Huisache (*Acacia minuata*) and retama (*Parkinsonia aculeata*). Ground cover is a *Paspalum* species (no inforescesces for identification). The site is riprian.

Site 7d - Rangerville. Mesquite (*Prosopis glandulosa*) is dominant. Also present are huisache (*Acacia minuata*), anacua (*Ehretia anacua*), and sugar hackberry (*Celtis laevigata*). Guineagrass (*Panicum maximum*) forms a solid ground cover. The site is riparian.

Site 8a - East of Rangerville. Sugar hackberry (*Celtis laevigata*) is dominant. Tenaza (*Chloroleucon pallens*), retama (*Parkinsonia aculeata*), brazil (*Condalia hookeri*), and granjeno (*Celtis pallida*) are present. Guineagrass (*Panicum maximum*) forms the ground cover.The site is riparian.

Site 8b - East of Rangerville. Can't discern a dominant. Species present are huisache (*Acacia minuata*), tepeguaje (*Leucaena pulverulenta*), sugar hackberry (*Celtis laevigata*), chinaberry (*Melia azedarach*), and a big clump of brazilian pepper (*Rhus terrabentifolia*). Guineagrass (*Panicum maximum*) forms the ground cover. The site is riparian.

Site 8c - East of Rangerville. Ebony (*Chloroleucon ebano*) is dominant. Mesquite (*Prosopis glandulosa*) is common. Also present are coma (*Sideroxylon celastrina*), brazil (*Condalia hookeri*), lotebush (*Ziziphus obtusifolia*), granjeno (*Celtis pallida*), and snake eyes (*Phaulothamnus spinescens*). Guineagrass (*Panicum maximum*) forms the ground cover. The site is riparian.

Site 8d - East of Rangerville. Sugar hackberry (*Celtis laevigata*) is dominant. Also present are mesquite (*Prosopis glandulosa*), ebony (*Chloroleucon ebano*), catclaw (*Acacia greggi*ii), tenaza (*Chloroleucon pallens*), tanglewood (*Forestiera angustifolia*) and crucillo (*Randia rhagocarpa*). Guineagrass (*Panicum maximum*) forms the ground cover. The site is riparian.

Site 8e - East of Rangerville. Sugar hackberry (*Celtis laevigata*) and mesquite (*Prosopis glandulosa*) are dominant. Guineagrass (*Panicum maximum*) forms the groundlayer. The site is riparian.

Site 8f - East of Rangerville. Mesquite (*Prosopis glandulosa*) is dominant. Sugar hackbery (*Celtis laevigata*) and granjeno (*Celtis pallida*) are present. Guineagrass (*Panicum maximum*) forms the ground layer. The site is riparian.

Site 9a - Southwest of San Benito. Sugar hackberry (*Celtis laevigata*) is dominant. Ebony (*Chloroleucon ebano*) and huisache (*Acacia minuata*) are present. Guineagrass (*Panicum maximum*) forms ground layer. The site is riparian.

Site 9b - Southwest of San Benito. Sugar hackberry (*Celtis laevigata*) is dominant. The adjacent field is an orange grove. The site is riparian. The vegetation is not.

Site 9c - Southwest of San Benito. This site appears to have been mostly cleared since the imagery was taken. There are houses here now. Only sugar hackberrys (*Celtis laevigata*) are left. These are scattered. The site is riparian. The vegetation is not.

Site 9d - Southwest of San Benito. Sugar hackberry (*Celtis laevigata*) is dominant. Tenaza (*Chloroleucon ebano*) and brazil (*Condalia hookeri*) are present. Guineagrass (*Panicum maximum*) forms the ground layer. The site is riparian.

Site 9e - Southwest of San Benito. Ebony (*Chloroleucon ebano*) and brazil (*Condalia hookeri*) are co-dominants. Guineagrass (*Panicum maximum*) forms the ground layer. The site is riparian.

Site 10a - Southwest of San Benito on FM 2520. A new house is being built on this site. The vegetation has been cleared.

Site 10b - Southwest of San Benito on FM 2520. Trees include black willow (*Salix nigra*), mulberry (*Morus rubra*), and popinac (*Leucaena leucocephala*). China berry (*Melia azedarach*) is present on the margin. Pepervine (*Ampelopsis arborea*) froms a cover over many of the trees and shrubs and is likely the dominant vegetation seen in imagery. Mesquite (*Prosopis glandulosa*) and hackberry (*Celtis levigata*) are shrubs here. The site is highly disturbed. It may have been riparian in the past.

Site 10c - Southwest of San Benito on FM 2520. Mesquite (*Prosopis glandulosa*) and brazil (*Condalia hookeri*) are co-dominants here. Catclaw (*Acacia greggii*) is also a tree here. Barbados cherry (*Malphigia glabra*) is a common small shrub. The site is close to a resaca and may hve been riparian in the past. The vegetation is not riparian now.

Site 10d - Southwest of San Benito on FM 2520. Mesquite (*Prosopis glandulosa*) is the dominant tree. Shrubs present include, granjeno (*Celtis pallida*), lotebush (*Ziziphus obtusifolia*), snake eyes (*Phaulothamnus spinescens*), ebony (*Chloroleucon ebano*), colima (*Zanthoxylum fagara*), catclaw (*Acacia greggii*), and goat bush (*Castela texana*). The ground cover is sparse. The site is on the margin of a resaca, but the vegetation does not appear to be riparian.

Site 11a - Villa Cavazos. Ebony (*Chloroleucon ebano*) is the dominant tree. Mesquite (*Prosopis glandulosa*) and huisache (*Acacia minuata*) are also present. the shrub layer includes granjeno (*Celtis pallida*), tenaza (*Chloroleucon pallens*), snake eyes (*Phaulothamnus spinescens*), vasey adelia (*Adelia vaseyi*) and lotebush (*Ziziphus obtusifolia*). The site is not riparian.

Site 11b - Villa Cavazos. Mesquite (*Prosopis glandulosa*) is dominant. Huisache (Acacia minuata) and ebony (*Chloroleucon ebano*) aare also present. Retama (*Parkinsonia aculeata*) and tenaza (*Chloroleucon ebano*) are shrubs here. Guineagrass (*Panicum maximum*) forms the ground layer. The site is not riparian.

Site 11c - Villa Cavazos. This site is a field of huisache (*Acacia minuata*) all of the same height. Appears to be planted. There is large mesquite (*Prosopis glandulosa*) and hackberry (*Celtis llaevigata*) in the fence line adjacent to the highway. The site is not riparian.

Site 11d - Villa Cavazos. Retama (Parkinsonia aculeata) is donminant. Huisache (*Acacia minuata*) and ebony (*Chloroleucon ebano*) are present. Amantillo (*Abutilon trisulcatum*) is present. Bermuda grass (*Cynodon dactylon*) forms the ground cover. The site is highly disturbed. It is not riparian.

Site 12a -Southeast of Villa Cavazos. Very large tepeguaje (*Leucaena pulverulenta*) and hackberry (*Celtis laevigata*) are co-dominants. The shrub layer includes anacua (*Ehretia anacua*) and lotebush (*Condalia obtusifolia*).Guineagrass (*Panicum maximum*) forms the ground layer. Turk's cap(*Malvaviscus arborea*) is present in the ground layer. The site is riparian.

Site 12b - Southeast of Villa Cavazos. Hackberry (*Celtis laevigata*) is dominant. Other trees present are mequite (*Prosopis glandulosa*) and anacua (*Ehretia anacua*). Shrubs present include granjeno (*Celtis pallida*) and lotebush (*Condalia obtusifolia*). marine ivy (*Cissus incisa*) and correhuela (*Cocculus diversifolius*) form an extensive vine cover on the trees and shrubs. Guineagrass (*Panicum maximum*) forms the ground cover. The site is riparian.

Site 12c - Southeast of Villa Cavazos. Retama (*Parkinsonia aculeata*) is dominant. Mesquite (*Prosopis gladulosa*) is also present. Guineagrass (*Panicum maximum*) forms the ground cover. The site is riparian.

Site 12d - Southeast of Villa Cavazos. Black willow (*Salix nigra*) is the dominant tree. hackberry (*Celtis laevigata*) is also present. Zarza (*Mimosa asperata*) is the principal shrub. Peppervine (*Ampelopsis arborea*) forms an extensive cover on the trees and shrubs. Guineagrass (*Panicum maximum*) forms the ground cover. The site is riparian.

Site 12e - Southeast of Villa Cavazos. Hackberry (*Celtis laevigata*) is the dominant tree. Retama (*Parkinsonia aculeata*) and black willow (*Salix nigra*) are present. Peppervine (*Ampelopsis arborea*) is abundant. Guineagrass (*Panicum maximum*) forms the ground cover. The site is riparian.

* Zarza (*Mimosa asperata*) forms a solid cover in the floor of the resaca between sites 12d and 12e.

Site 13a - North of Barreda Pump Bend. This site is adjacent to a private residence and an extensive farm equipment storage area. Large mesquites (*Prosopis glandulosa*) are dominant. Guineagrass (*Panicum maximum*) forms the ground cover. The site is distrubed and the vegetation does not now appear to be riparian.

Site 13b - North of barreda Pump Bend. This site is at a private residence to the east and farm equipment storage area. It is highly disturbed and does not appear to be riparian vegetation now. Large mesquites (*Prosopis glandulosa*) are dominant. Granjeno (*Celtis pallida*) is sparse as a shrub. Guineagrass (*Panicum maximum*) forms the ground cover.

Site 14a - Resaca de la Plama. Ebony (*Chloroleucon ebano*) is dominant. There are some mesquites (*Prosopis glandulosa*) in the tee layer, but they are not as abundant as ebony. Shrubs present are guayacan (*Guaiacum angustifolium*), granjeno (*Celtis pallida*), snake - eyes (*Phaulothamnus spinescens*), panalero (*Forestiera angustifolia*) and lotebush (*Ziziphus obtusifolia*). The ground under the trees and shrubs is bare. There is planted huisache (*Acacia minuata*) on the east side of the road at this site. The site does not appear to be riparian. This is TPWD land. Must have a key to gain access. Fortunately, Bob has one.

Site 14b - Resaca de la Palma. This is in a more open community, but we could not ascertain the location.

Site 14c - Resaca de la Palma. This site is best classified as mixed brush. It is difficult to discern a dominant. Ebony (*Chloroleucon ebano*) is of short stature. Species present include coma (*Sideroxylon celastrina*), guayacan (*Guaiacum angustifolium*), colima (*Zanthoxylum fagara*), panalero (*Forestiera angustifolia*) and snake-eyes (*Phaulothamnus spinescens*). The ground is bare under the shrubs. the site does not appear to be riparian.

Site 14d - Ebony (*Chloroleucon ebano*) is dominant. Mesquite (*Prosopis glandulosa*) is also present in the tree layer. Trees are very tall. Tenaza (*Havardia pallens*) is a tree here. Other species in the tree layer are tepeguaje (*Leucaena pulverulenta*), and mountain torchwoood (*Amyris madrensis*). The community is open under the trees and one can stand upright and move around with ease. (*Tillandsia baileyi*) is present growing on a *Cocculus diversifolia* vine. Shrubs present include oreja de raton (*Bernardia myricaefolia*), snake-eyes (*Phaulothamnus spinescens*), granjeno (*Celtis pallida*), crucillo (*Randia rhagocarpa*), guayacan (*Guaiacum angustifolium*), chapote (*Diospyros texana*), and coyotillo (*Karwinskia hunboldtiana*). This site is riparian. Guineagrass (*Panicum maximum*) forms a sparse ground cover. there are very large hackberry trees on the west side of the road at this site. Also present on the west side are very large tepeguaje (*Leucaena pulverulenta*), anacua (*Ehretia anacua*), and cedar elm (*Ulmus crassifolia*). These species are very close to the resaca edge. the aspect changes to mre xeric and cled brush community as one goes away from the resaca. On the northeast side of the road across the resaca from this site are some large hackberrys (*Celtis laevigata*) that reach heights of 20 m or more.

Site 14e - Resaca de la Palma. The gray signature in the image is retama (*Parkinsonia aculeata*) with a thick stand of black mimosa or zarza (*Mimosa asperata*). This community grows out in the resaca somewhat at the higher slopes of the banks. The ground cover includes guineagrass (*Panicum maximum*), longtom (*Paspalum lividum*) and *Pennisetum* sp.

Appendix 2. Anzalduas Park

27 July 2000. World Wildlife Refuge adjacent to Anzalduas Park. 1.05 miles west of gate at a site where river is near the road. Hidalgo County, Texas. Riparian vegetation.

Transect 1

(Transect starts in water 6"deep; in Phragmites)

0-10 meters	% cover	Rel. cover	
Ground layer			
Panicum maximum	85.0		
Shrub layer			
Phragmites australis	30.0		
Tree layer			
Salix nigra	85.0	67.5	
Salix exigua	41.0	32.5	
	126.0		
Tree density, height (m), and dbh			
Salix nigra (1)	15.0 m		59.5 cm
Salix exigua (1)	5.5		23.0

....

10-20 meters			
(top of terrace is at 11.0 meters)			
Ground layer			
Panicum maximum	100.0	99.6	
Ehretia anacua	0.4	0.4	
	100.4		
NO SHRUBS			
Tree layer			
Celtis laevigata	91.0	85.0	
Salix nigra	16.0	15.0	
	107.0		
Tree density, height, dbh			
Celtis laevigata (3)	4.8, 9.0, 9.5		3.0, 20.2, 16.2
Salix nigra (1)	6.9		28.0

....

20-30 meters			
Ground layer			
Panicum maximum	62.7	80.3	
Cenchrus ciliaris	15.4	19.7	
	78.1		
Shrub layer			
Celtis pallida	15.0		
Shrub density, height, dbh			
Celtis pallida (1)	2.8		2.4
Tree layer			
Prosopis glandulosa	72.0	70.6	
Celtis laevigata	30.0	29.4	
	102.0		

Appendix 2. Anzalduas Park

Tree density, height, and dbh		
Prosopis glandulosa (1)	5.5	39.0

(C. laevigata was in the last interval)

…………………..

Transect 1. Summary of three intervals (30 m).

Ground layer	Freq.	Rel. freq.	% cover	Rel. cover	IV
Panicum maximum	100.0	60.0	82.57	94.0	154.0
Cenchrus ciliaris	33.3	20.0	5.13	5.8	25.8
Ehretia anacua	33.3	20.0	0.40	0.2	20.2
			87.83		
Shrub layer					
Phragmites australis	33.3	50.0	30.0	66.7	116.7
Celtis pallida	33.3	50.0	15.0	33.3	83.3
			45.0		

Shrub density, height, dbh
Phragmites australis (height and dbh not determined)

Celtis pallida (1)	2.8 m	2.4 cm

Tree layer	Freq.	Rel. freq.	% cover	Rel. cover	IV
Celtis laevigata	66.7	33.3	40.33	36.1	69.4
Salix nigra	66.7	33.3	33.67	30.1	63.4
Prosopis glandulosa	33.3	16.7	24.00	21.5	38.2
Salix exigua	33.3	16.7	13.67	12.2	28.9
			111.67		

Tree density, height, dbh		
Salix nigra (2)	15.0, 6.9	59.5
Salix exigua (1)	5.5	23.0
Celtis laevigata (3)	4.8, 9.0, 9.5	3.0, 20.2, 16.2
Prosopis glandulosa (1)	5.5	39.0
7 trees		

Transect 2.

(20 paces upriver from Transect 1; transect begins in 6" of water

0-10 meters

Ground layer		
Panicum maximum	23.0	
Shrub layer		
Phragmites australis	100.0	

(height, and dbh not determined)

Tree layer		
Salix nigra	100.0	54.6
Salix exigua	83.0	45.4
	183.0	

(Celtis laevigata = missing cover data)

Appendix 2. Anzalduas Park

Tree density, height, dbh			
Salix exigua (2)	4.8, 4.5		3.6, (3.5, 3.0, 1.5)
Salix nigra (1)	9.5		41.6
Celtis laevigata (2)	6.5, 10.0		11.9, 20.6

……………………

(top of 1st terrace is at 13.0 meters)

10-20 meters

Ground layer			
Panicum maximum	94.1		
Shrub layer			
Celtis pallida	2.4		
Shrub density, height, dbh			
Celtis pallida (1)	2.7		1.5
Tree layer			
Celtis laevigata	100.0		
Tree density, height, dbh			
Celtis laevigata (3)	7.0, 12.5, 4.7		17.4, 19.4, 6.0

…………………………..

20-30 meters

Ground layer			
Panicum maximum	95.2		
NO SHRUBS			
Tree layer			
Celtis laevigata	71.0		
Tree density, height, dbh			
Celtis laevigata (2)	7.5, 8.0		6.4, 13.3

………………………

30-40 meters

(30 meters is at the foot of the 2nd slope; crest of 2nd terrace is at 39.0 meters)

Ground layer			
Cenchrus ciliaris	48.4	60.2	
Panicum maximum	32.0	39.8	
	80.4		
Shrub layer			
Karwinskia humboldtiana	20.5		
Shrub density, height, dbh			
Karwinskia humboldtiana (2)	2.0 m, 2.6 m		1.8 cm, 2.6 cm, 2.2 cm
Tree layer			
Celtis laevigata	33.0	88.7	
Celtis pallida	4.2	11.3	
	37.2		
Tree density, height, and dbh			
Celtis laevigata (1)	8.0		13.3
Celtis pallida (1)	3.3		4.2

Appendix 2. Anzalduas Park

Transect 2. Summary of four intervals (40 m).

Ground layer	Freq.	Rel. freq.	% cover	Rel. cover	IV
Panicum maximum	100.0	80.0	61.08	83.5	163.5
Cenchrus ciliaris	25.0	20.0	12.10	16.5	36.5
			73.18		
Shrub layer					
Phragmites australis	25.0	33.3	25.00	81.4	114.7
Karwinskia humboldtiana	25.0	33.3	5.13	16.7	50.0
Celtis pallida	25.0	33.3	0.60	2.0	35.3
			30.73		

Shrub density, height, dbh		
Karwinskia humboldtiana (2)	2.0, 2.6	1.8, (2.6, 2.2)
Celtis pallida (1)	2.7 m	1.5 cm
3 shrubs		

Tree layer					
Celtis laevigata	75.0	50.0	51.00	52.1	102.1
Salix nigra	25.0	16.7	25.00	25.6	42.3
Salix exigua	25.0	16.7	20.75	21.2	37.9
Celtis pallida	25.0	16.7	1.05	1.1	17.8
			97.80		

Tree density, height, dbh		
Salix exigua (2)	4.8, 4.5	3.6, (3.5, 3.0, 1.5)
Salix nigra (1)	9.5	41.6
Celtis laevigata (7)	6.5, 10.0, 7.0, 12.5, 4.7, 7.5, 8.0	11.9, 20.6, 17.4, 19.4, 6.0, 6.4
Celtis pallida (1)	3.3	4.2
11 trees		

Transect 3. (20 paces upstream from Transect 2)

0-10 meters

Ground layer

NO HERBACEOUS PLANTS IN GROUND LAYER

Shrub layer		
Phragmites australis	100.0	
Tree layer		
Celtis laevigata	39.0	52.0
Salix exigua	36.0	48.8
	75.0	

Tree density, height, dbh		
Salix exigua (2)	4.0, 4.5	(1.2, 0.5), 13.4

....

10-20 meters

(top of the 1st terrace is at 10.0 meters)

Ground layer

Panicum maximum	83.2

Appendix 2. Anzalduas Park

Shrub layer					
Phragmites australis	8.8	57.5			
Celtis laevigata	3.3	21.6			
Celtis pallida	3.2	20.9			
	15.3				
Shrub density, height, dbh					
Celtis pallida (1)	1.85		0.5		
Celtis laevigata (1)	2.5		1.9		
Tree layer					
Celtis laevigata	100.0				
Tree density, height, dbh					
Celtis laevigata	8.5		22.3		
....					
20-30 meters					
(horse trail is at 25.50-25.80 meters)					
Ground layer					
Panicum maximum	97.0				
Shrub layer					
Celtis pallida	33.0				
Shrub density, height, dbh					
Celtis pallida (1)	2.35		(3.0, 3.4, 2.8)		
Tree layer					
Celtis laevigata	60.0	92.6			
Ehretia anacua	4.8	7.4			
	64.8				
....					
30-40 meters					
Ground layer					
Panicum maximum	66.8	83.0			
Cenchrus ciliaris	10.5	13.0			
Setaria leucopila	3.2	4.0			
	80.5				
NO SHRUBS					
Tree layer					
Celtis laevigata	55.5	75.3			
Celtis pallida	18.2	24.7			
	73.7				
Tree density, height, dbh					
Celtis laevigata (2)	6.5, 7.0		10.4, (8.7, 8.1, 7.5)		
Celtis pallida (1)	5.1		8.6		
....					
Transect 3. Summary of four intervals (40 m).					
Ground layer					
Panicum maximum	75.0	60.0	61.75	94.7	154.7
Cenchrus ciliaris	25.0	20.0	2.63	4.0	24.0
Setaria leucopila	25.0	20.0	0.80	1.2	21.2
			65.18		

Appendix 2. Anzalduas Park

Shrub layer					
Phragmites australis	50.0	40.0	27.20	73.4	113.4
Celtis pallida	50.0	40.0	9.05	24.4	64.4
Celtis laevigata	25.0	20.0	0.83	2.2	22.2
			37.08		

Shrub density, height, dbh		
Celtis pallida (2)	1.85, 2.35	0.5, (3.0, 3.4, 2.8)
Celtis laevigata (1)	2.5	1.9

Tree layer					
Celtis laevigata	100.0	57.1	63.63	81.2	138.3
Salix exigua	25.0	14.3	9.00	11.5	25.8
Celtis pallida	25.0	14.3	4.55	5.8	20.1
Ehretia anacua	25.0	14.3	1.20	1.5	15.8
			78.38		

Tree density, height, dbh		
Salix exigua (2)	4.0, 4.5	(1.2, 0.5), 13.4
Celtis laevigata (6)	8.5, 8.5, 5.2, 7.2 6.5, 7.0	22.3, 12.9, 3.9, 10.7
Ehretia anacua (1)	3.45	1.0
Celtis pallida (1)	5.1	8.6
10 trees		

Summary of three transects (110 meters). Pooled data.

Ground layer					
Panicum maximum	90.9	66.7	67.18	90.5	157.2
Cenchrus ciliaris	27.3	20.0	6.75	9.1	29.1
Setaria leucopila	9.1	6.7	0.29	0.4	7.1
Ehretia anacua	9.1	6.7	0.04	<0.1	6.7
			74.26		

Shrub layer					
Phragmites australis	36.4	40.0	21.71	75.5	115.5
Celtis pallida	36.4	40.0	4.87	17.0	57.0
Karwinskia humboldtiana	9.1	10.0	1.86	6.5	16.5
Celtis laevigata	9.1	10.0	0.30	1.0	11.0
			28.74		

Shrub density, height, dbh		
Celtis pallida (4)	2.8, 2.7, 1.85, 2.35	2.4, 1.5, 0.5, (3.0, 3.4, 2.8)
Karwinskia humboldtiana (2)	2.0, 2.6	1.8, (2.6, 2.2)
Celtis laevigata (1)	2.5	1.9

Tree layer					
Celtis laevigata	81.8	47.4	52.68	55.0	102.4
Salix nigra	27.3	15.8	18.27	19.1	34.9
Salix exigua	27.3	15.8	14.55	15.2	31.0
Celtis pallida	18.2	10.5	2.04	2.1	12.6
Prosopis glandulosa	9.1	5.3	6.55	6.8	12.1
Ehretia anacua	9.1	5.3	1.65	1.7	7.0
			95.74		

Appendix 2. Anzalduas Park

Tree density, height, dbh		
Salix nigra (3)	15.0, 6.9, 9.5	59.5, 28.0, 41.6
Salix exigua (5)	5.5, 4.8, 4.5, 4.0, 4.5	23.0, 3.6, (3.5, 3.0, 1.5), (1.2, 0.5), 13.4
Prosopis glandulosa (1)	5.5	39.0
Celtis pallida (2)	3.3, 5.1	4.2, 8.6
Ehretia anacua (1)	3.45	1.0
Celtis laevigata (15)	4.8, 9.0, 9.5, 8.5, 5.2, 7.2, 6.5, 7.0, 6.5, 10.0, 7.0, 12.5, 4.7, 7.5, 8.0	3.0, 20.2, 16.2, 22.3, 12.9, 3.9, 10.7, 11.9, 20.5 17.4, 19.4, 6.0, 6.4

5 May 2000. Riparian vegetation. Bentsen-Rio Grande Valley State Park. At trailhead of the river; upriver about 75 m to first transect. A large *Salix nigra* and a huisache is arching over the river at this site. Compass bearing on the river trend is 315° W. Transect compass is 45° N. Transect begins at river's edge in mud. Muddy soil ends at 4.20 meters; bank begins at 4.20 meters. On flat top of river bank at 7.30 meters.

Transect 1.

Ground layer

0-10 meters	% cover	Rel. cover
Panicum maximum	51.2	90.8
Paspalum lividum	4.4	7.8
Cyperus ochraceus	0.8	1.4
	56.4	

10-20 meters
(Depression begins at 11.30 meters; bottom of depression at 15.50 meters)

Panicum maximum	53.1

20-30 meters
(Sandy slope)

Panicum maximum	66.8

....

Transect 1. Summary

	Freq.	Rel. freq.	% cover	Rel. cover	IV
Panicum maximum	100.0	60.0	57.03	97.1	157.1
Paspalum lividum	33.3	20.0	1.47	2.5	22.5
Cyperus ochraceus	33.3	20.0	0.27	0.5	20.5
			58.77		

....

Transect 1. Cover values. **Tree and shrub layer.** % cover and relative cover.

0-10 meters		
Acacia minuata (smallii)	100.0	62.3
Celtis laevigata	60.5	37.7
	160.5	

10-20 meters		
Celtis laevigata	62.0	55.4
Prosopis glandulosa	50.0	44.6
	112.0	

20-30 meters		
Celtis laevigata	90.0	45.0
Celtis pallida	56.0	28.0

Prosopis glandulosa	46.0	23.0
Condalia hookeri	8.0	4.0
	200.0	

Transect 1. Cover values. Tree and shrub layer. Summary. Frequency, relative frequency, % cover, relative cover, and importance value.

Celtis laevigata	100.0	37.5	70.8	45.0	82.5
Prosopis glandulosa	66.7	25.0	32.0	20.3	45.3
Acacia minuata	33.3	12.5	33.3	21.2	33.7
Celtis pallida	33.3	12.5	18.7	11.9	24.4
Condalia hookeri	33.3	12.5	2.7	1.7	14.2
			157.5		

....

Transect 1. Tree and shrub density. Heights and diameters (dbh).

	Heights (m)	Diameters (cm)
0-10 meters		
Celtis laevigata (4)	9.0, 3.5, 3.3, 3.3	3.6, 3.9, 4.1
Acacia minuata (1)	10.0	32.2, 24.9
10-20 meters		
Celtis laevigata (7)	2.2, 3.5, 4.3, 3.4, 2.4 2.4, 3.2	1.3, 2.5, 4.6, 3.9, 1.4, 2.9, 3.3, 1.8
Prosopis glandulosa (1)	12.0	29.6

Transect 2. Ground layer. Transect is 10 meters upstream from Transect 1. An old refrigerator is on the margin of the river.
% cover and relative cover.

0-10 meters		
Panicum maximum	26.7	98.2
Vigna luteola	0.5	1.8
	27.2	
10-20 meters		
(Down slope at 12.0 meters)		
Panicum maximum	46.8	
20-30 meters (top of terrace)		
Panicum maximum	77.2	99.4
Cocculus diversifolius	0.5	0.6
	77.7	

....

Transect 2. Ground layer. Summary of three intervals. Frequency, relative frequency, % cover, relative cover, and importance value.

Panicum maximum	100.0	60.0	50.23	99.3	159.3
Vigna luteola	33.3	20.0	0.17	0.3	20.3
Cocculus diversifolius	33.3	20.0	0.17	0.3	20.3
			50.57		

Transect 2. **Tree and shrub layer.** % cover and relative cover

0-10 meters		
Phragmites australis	46.0	53.5
Celtis laevigata	40.0	46.5
	86.0	
10-20 meters		
Celtis laevigata	100.0	
20-30 meters		
Celtis laevigata	47.0	42.9
Prosopis glandulosa	36.0	32.9
Condalia hookeri	18.0	16.4
Celtis pallida	8.5	7.8
	109.5	

Transect 2. Tree and shrub layer cover. Summary of three intervals. Frequency, relative frequency, % cover, relative cover, and importance value.

Celtis laevigata	100.0	42.9	62.33	63.3	106.2
Phragmites australis	33.3	14.3	15.33	15.6	29.9
Prosopis glandulosa	33.3	14.3	12.00	12.2	26.5
Condalia hookeri	33.3	14.3	6.00	6.1	20.4
Celtis pallida	33.3	14.3	2.83	2.9	17.2
			98.49		

Transect 2. **Tree and shrub densities**. Heights (m) and diameters (cm); dbh.

0-10 meters		
Celtis laevigata (1)	8.0	18.1, 2.3
Phragmites australis	4.0	(large colony)
10-20 meters		
Celtis laevigata (5)	2.6, 4.5, 3.6, 15.0, 2.3	3.0, 3.9, 4.7, 2.3, 40.6

20-30 meters		
Celtis laevigata (1)	12.5	16.0
Celtis pallida (1)	3.6	1.6
Condalia hookeri (1)	3.7	4.7
Prosopis glandulosa (1)	13.0	28.0

Transect 3. Ground layer. Cover values; % cover and relative cover. Transect 3 is 10 meters north of Transect 2. In dense cane colony.

0-10 meters		
Panicum maximum	26.5	(Dry soil at 4.0 meters)
10-20 meters (Bottom of depression at 12.18 – 12.91 meters)		
Panicum maximum	68.0	99.7
Cocculus diversifolius	0.2	0.3
	68.2	
20-30 meters (Crest of terrace at 21.50 meters)		
Panicum maximum	18.4	92.5
Cocculus diversifolius	1.5	7.5
	19.9	

Transect 3. Ground layer. Summary of three intervals. Frequency, relative frequency, % cover, relative cover, and importance value.

Panicum maximum	100.0	60.0	37.63	98.5	158.5
Cocculus diversifolius	66.7	40.0	0.57	1.5	41.5
			38.20		

Transect 3. **Tree and shrub layer.** Cover values; % cover and relative cover.

0-10 meters		
Arundo donax	84.0	41.6
Celtis laevigata	60.0	29.7
Acacia minuata	38.0	18.8
Salix nigra	20.0	9.9
	202.0	
10-20 meters		
Celtis laevigata	64.0	34.8
Salix nigra	54.0	29.3
Arundo donax	54.0	29.3
Celtis pallida	12.0	6.5
	184.0	

20-30 meters	
Celtis pallida	39.5

....

Transect 3. Tree and shrub layer. Cover values; summary of three intervals. Frequency, relative frequency, % cover, relative cover, and importance values.

Arundo donax	66.7	22.2	46.00	32.4	54.6
Celtis laevigata	66.7	22.2	41.33	29.1	51.2
Salix nigra	66.7	22.2	24.67	17.4	39.6
Celtis pallida	66.7	22.2	17.17	12.1	34.3
Acacia minuata	33.3	11.1	12.67	8.9	20.0
			141.84		

....

Transect 3. Tree and shrub densities. Heights (m) and diameter (dbh) (cm).

0-10 meters		
Arundo donax (colony)	4.0	2.4 (many culms)
Acacia minuata (1)	5.5	23.0, 36.5
Salix nigra (1)	18.0	(inaccessible)
Celtis laevigata	___	4.0, 12.2, 10.8, 9.4
10-20 meters		
Celtis pallida (1)	3.4	1.0, 2.0, 1.5
Celtis laevigata (3)	5.5, 4.2, 4.9	4.4, 7.0, 5.1, 5.2
Arundo donax (colony)	5.0	
Salix nigra (1)	18.0	44.5
20-30 meters		
Celtis pallida (5)	3.7, 3.6, 2.8, 3.5, 2.9	2.0, 2.7, 2.0, 1.0, 0.9, 2.1, 1.3, 4.6, 3.7, 2.1, 1.5, 1.9, 2.2

Ground layer. Pooled values for three transects (90 meters). Frequency, relative frequency, % cover, relative cover, and importance values.

Panicum maximum	100.0	60.0	48.30	98.2	158.2
Cocculus diversifolius	33.3	20.0	0.24	0.5	20.5
Paspalum lividum	11.1	6.7	0.49	1.0	7.7
Cyperus ochraceus	11.1	6.7	0.09	0.2	6.9
Vigna luteola	11.1	6.7	0.06	0.1	6.8
			49.18		

....

Tree and shrub layer. Pooled values for three transects (90 meters). Frequency, relative frequency, % cover, relative cover, and importance values.

Celtis laevigata	88.9	33.3	58.17	43.9	77.2
Celtis pallida	44.4	16.7	12.89	9.7	26.4
Prosopis glandulosa	33.3	12.5	14.67	11.1	23.6
Arundo donax	22.2	8.3	15.33	11.6	19.9
Acacia minuata	22.2	8.3	15.33	11.6	19.9
Salix nigra	22.2	8.3	8.22	6.2	14.5
Condalia hookeri	22.2	8.3	2.89	9.7	10.5
Phragmites australis	11.1	4.2	5.11	3.9	8.1
			132.61		

Appendix 2. Escobares

22 August 2001. Riparian vegetation at Escobares. Starr County, Texas.

Transect 1			
Ground layer	% cover	Rel. cover	
0-10 meters			
Celtis laevigata	17.8	65.7	
Chromolaena odorata	5.5	20.3	
Boerhavia scandens	1.9	7	
Ziziphus obtusifolia	1.4	5.2	
Malvastrum coromandelianum	0.5	1.8	
Total cover	27.1		
10-20 meters			
Chromolaena odorata	1.2	4.8	
Celtis laevigata	0.8	3.2	
Cocculus diversifolius	0.2	0.8	
Condalia hookeri	0.3	0.6	
Total cover	2.5		
20-30 meters			
Pennisetum ciliare	2.7		
Shrub layer ( ) = # of individuals			
0-10 meters			
Condalia hookeri (1)	17.4		
10-20 meters			
Celtis pallida (2)	12.7		
20-30 meters			Height (m)
Celtis pallida (3)	37	97.6	2.3, 2.9, 2.7
Ziziphus obtusifolia (1)	0.9	2.4	1.3
Total cover	37.9		
Tree layer			
0-10 meters			
Prosopis glandulosa (1)	84	69.2	10.5 m
Condalia hookeri (3)	36.1	29.8	5.4, 4.3, 4.2 m
Celtis pallida (1)	1.2	1	4.4 m
Total cover	121.3		
10-20 meters			
Prosopis glandulosa (2)	100	64.4	5.4, 9.2 m
Celtis pallida (5)	51.2	33	4.45, 4.3, 3.6, 3.5, 3.7
Condalia hookeri (1)	4	2.6	5.1 m
Total cover	155.2		
20-30 meters			
Prosopis glandulosa (2)	67.5		5.4, 4.1

Transect 1. Summary. 30 meters

Ground layer

Appendix 2. Escobares

Species	Freq.	Rel. freq.	% cover	Rel. cover	IV
Celtis laevigata	66.7	20	6.2	57.6	77.6
Chromolaena odorata	66.7	20	2.23	20.7	40.7
Pennisetum ciliare	33.3	10	0.9	8.4	18.4
Boerhavia scandens	33.3	10	0.63	5.9	15.9
Ziziphus obtusifolia	33.3	10	0.47	4.3	14.3
Malvastrum coromandelianum	33.3	10	0.17	1.5	11.5
Condalia hookeri	33.3	10	0.1	0.9	10.9
Cocculus diversifolius	33.3	10	0.07	0.7	10.7
Total cover			10.77		
Shrub layer					
Celtis pallida (5)	66.7	50	16.87	73.4	123.4
Condalia hookeri (1)	33.3	25	5.8	25.3	50.3
Ziziphus obtusifolia (1)	33.3	25	0.3	1.3	26.3
Total cover			22.97		
7 shrubs					
Tree layer					
Prosopis glandulosa (5)	100	42.9	83.83	73.1	116
Celtis pallida (6)	66.7	28.6	17.47	15.2	43.8
Condalia hookeri (4)	66.7	28.6	13.37	11.7	
Total cover			114.67		
15 trees in Transect 1					

Transect 2

Ground layer	% cover	Rel. cover
0-10 meters		
Chromolaena odorata	3.3	34.4
Celtis laevigata	3.1	32.3
Cynodon dactylon	1.1	11.5
Boerhavia scandens	1.1	11.5
Setaria leucopila	0.6	6.3
Cocculus diversifolius	0.4	4.2
Total cover	9.6	
10-20 meters		
Guaiacum angustifolium	1.8	48.6
Celtis pallida	0.7	18.9
Ziziphus obtusifolia	0.6	16.2
Celtis laevigata	0.3	8.1
Chromolaena odorata	0.3	8.1
Total cover	3.7	
20-30 meters		
Celtis pallida	7.1	51.4
Pennisetum ciliare	3.9	28.3
Condalia hookeri	1.4	10.1
Opuntia engelmannii	1	7.2
Chenopodium sp.	0.3	2.2
Total cover	13.8	

Appendix 2. Escobares

Shrub layer

0-10 meters			Height (m)
Celtis pallida (2)	12.3	57.7	2.4, 1.2
Celtis laevigata (1)	9	42.3	2.8 m
Total cover	21.3		
10-20 meters			
Ziziphus obtusifolia (1)	9		2.9 m
20-30 meters			
Condalia hookeri (3)	36.5	54.1	1.7, 1.4, 2.7 m
Prosopis glandulosa (1)	21	31.1	2.2 m
Celtis pallida (1)	10	14.8	1.8 m
Total cover	65.5		

Tree layer

0-10 meters			
Celtis laevigata (8)	100	54.6	4.5, 4.2, 6.2, 5.4, 9.0, 3.3, 11.0, 4.0 m
Prosopis glandulosa (1)	57	31.1	9.5 m
Celtis pallida (1)	26	14.2	3.3 m
	183		
10-20 meters			
Prosopis glandulosa (1)	100	52.9	9.5 m
Condalia hookeri (4)	82	43.4	4.1, 5.7, 7.0, 6.1
Celtis laevigata (1)	7	3.7	4.2 m
Total cover	189		
20-30 meters			
Condalia hookeri (1)	13.5		4.7 m

Transect 2. Summary. 30 meters

Ground layer	Freq.	Rel. freq.	% cover	Rel. cover	IV
Celtis pallida	66.7	11.8	2.6	28.8	40.6
Chromolaena odorata	66.7	11.8	1.2	13.3	25.1
Celtis laevigata	66.7	11.8	1.13	12.5	24.3
Pennisetum ciliare	33.3	5.9	1.3	14.4	20.3
Setaria leucopila	66.7	11.8	0.23	2.6	14.4
Guaiacum angustifolium	33.3	5.9	0.6	6.6	12.5
Condalia hookeri	33.3	5.9	0.47	5.2	11.1
Boerhavia scandens	33.3	5.9	0.37	4.1	10
Cynodon dactylon	33.3	5.9	0.37	4.1	10
Opuntia engelmannii	33.3	5.9	0.33	3.7	9.6
Ziziphus obtusifolia	33.3	5.9	0.2	2.2	8.1
Cocculus diversifolius	33.3	5.9	0.13	1.5	7.4
Chenopodium sp.	33.3	5.9	0.1	1.1	7
Total cover			9.03		

Shrub layer

Celtis pallida (3)	66.7	33.3	7.43	22.8	56.1
Condalia hookeri (3)	33.3	16.7	12.2	37.3	54

Prosopis glandulosa (1)	33.3	16.7	7	21.5	38.2
Celtis laevigata (1)	33.3	16.7	3	9.2	25.9
Ziziphus obtusifolia (1)	33.3	16.7	3	9.2	25.9
Total cover			32.63		
Tree layer					
Celtis laevigata (9)	66.7	28.6	35.67	32	60.6
Prosopis glandulosa (2)	66.7	28.6	35.23	31.6	60.2
Condalia hookeri (5)	66.7	28.6	31.83	28.6	57.2
Celtis pallida (1)	33.3	14.3	8.67	7.8	22.1
Total cover			111.4		

Transect 3.

Ground layer	% cover	Rel. cover	
0-10 meters			
Cocculus diversifolius	4.9	83.1	
Condalia hookeri (5)	1	16.9	
Total cover	5.9		
10-20 meters			
Pennisetum ciliare	4.6	85.2	
Chromolaena odorata	0.3	5.6	
Celtis pallida	0.3	5.6	
Setaria leucopila	0.2	3.7	
Total cover	5.4		
20-30 meters			
Pennisetum ciliare	10.6	96.4	
Verbena officinalis	0.3	2.7	
Poaceae: Unidentified	0.1	0.9	
Total cover	11		
Shrub layer			
0-10 meters			Height (m)
Celtis pallida (1)	27	67.5	2.8 m
Celtis laevigata (1)	12	30	2.0 m
Condalia hookeri (1)	1	2.5	2.8 m
Total cover	40		
10-20 meters			
Ziziphus obtusifolia (1)	18	57.3	2.1 m
Celtis pallida (3)	13.4	42.7	1.5, 1.1, 1.6 m
Total cover	31.4		
20-30 meters			
Prosopis glandulosa (1)	7.5		2.4 m
Tree layer			
0-10 meters			
Prosopis glandulosa (2)	100	53.9	9.5, 3.5 m
Celtis laevigata (1)	38	20.5	4.0 m
Condalia hookeri (1)	20	10.8	3.3 m

Appendix 2. Escobares

Acacia minuata (1)	14	7.5		3.7 m
Celtis pallida (2)	13.5	7.3		3.7, 3.8
Total cover	185.5			
10-20 meters				
Prosopis glandulosa (1)	32	42.3		3.5 m
Celtis laevigata (2)	28	37		12.0, 4.2 m
Condalia hookeri (1)	15.7	20.7		4.0 m
Total cover	75.7			
20-30 meters				
Prosopis glandulosa (2)	43.3			10.0, 11.5 m

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Transect 3. Summary.		30 meters			
Ground layer	Freq.	Rel. freq.	% cover	Rel. cover	IV
Pennisetum ciliare	66.7	22.2	5.07	68.2	90.4
Cocculus diversifolius	33.3	11.1	1.63	22	33.1
Condalia hookeri	33.3	11.1	0.33	4.5	15.6
Chromolaena odorata	33.3	11.1	0.1	1.3	12.4
Celtis pallida	33.3	11.1	0.1	1.3	12.4
Verbena officinalis	33.3	11.1	0.1	1.3	12.4
Setaria leucopila	33.3	11.1	0.07	0.9	12
Poaceae: Unidentified	33.3	11.1	0.03	0.4	11.5
Total cover			7.43		
Shrub layer					
Celtis pallida (4)	66.7	33.3	13.47	51.2	84.5
Ziziphus obtusifolia (1)	33.3	16.7	6	22.8	39.5
Celtis laevigata (1)	33.3	16.7	4	15.2	31.9
Prosopis glandulosa (1)	33.3	16.7	2.5	9.5	26.2
Condalia hookeri (1)	33.3	16.7	0.33	1.3	18
Total cover			26.3		
Tree layer					
Prosopis glandulosa (5)	100	33.3	58.43	57.6	90.9
Celtis laevigata (3)	66.7	22.2	22	21.7	43.9
Condalia hookeri (2)	66.7	22.2	11.9	11.7	33.9
Acacia minuata (1)	33.3	11.1	4.67	4.6	15.7
Celtis pallida (2)	33.3	11.1	4.5	4.4	15.5
Total cover			101.5		

Summary of 3 x 30 meter transects at the Escobares site.

Ground layer					
Celtis laevi igata	44.4	11.1	2.44	26.9	38
Pennisetum ciliare	44.4	11.1	2.42	26.7	37.8
Chromolaena odorata	55.5	13.9	1.18	13	26.9
Celtis pallic da	33.3	8.3	0.9	9.9	18.2
Cocculus diversifolius	33.3	8.3	0.61	6.7	15
Condalia h ookeri	33.3	8.3	0.3	3.3	11.6
Setaria leucopila	33.3	8.3	0.1	1.1	9.4
Boerhavia scandens	22.2	5.6	0.33	3.7	9.3
Ziziphus obtusifolia	22.2	5.6	0.22	2.4	8

Guaiacum angustifolium	11.1	2.8	0.2	2.2	5
Cynodon dactylon	11.1	2.8	0.12	1.3	4.1
Opuntia engelmannii	11.1	2.8	0.11	1.2	4
Malvastrum coromandelianum	11.1	2.8	0.06	0.6	3.4
Chenopodium sp.	11.1	2.8	0.03	0.4	3.2
Verbena officinalis	11.1	2.8	0.03	0.4	3.2
Poaceae: Unidentified	11.1	2.8	0.01	0.1	2.9
Total cover			9.06		
Shrub layer					
Celtis pallida (12)	66.7	37.5	12.59	46.1	83.6
Condalia hookeri (5)	33.3	18.8	6.1	22.4	41.2
Ziziphus obtusifolia (3)	33.3	18.8	3.1	11.4	30.2
Prosopis glandulosa (2)	22.2	12.5	3.17	11.6	24.1
Celtis laevigata (2)	22.2	12.5	2.33	8.6	21.1
Total cover			27.29		
24 shrubs					
Tree layer					
Prosopis glandulosa (12)	88.9	34.8	59.17	54.2	89
Condalia hookeri (11)	66.7	26.1	19.03	17.4	43.5
Celtis laevigata (12)	44.4	17.4	19.22	17.6	35
Celtis pallida (9)	44.4	17.4	10.21	9.4	26.8
Acacia minuata (1)	11.1	4.3	1.56	1.4	5.7
Total cover			109.19		
45 trees					

La Joya Data

The La Joya site is located between our Bentsen State Park and Salineno sites. It is about 130.1 km west (up river) from Bentsen State Park. As at Bentsen State Park, hackberry, *Celtis laevigata*, is the dominant species in the tree layer (Table 1) and granjeno, *Celtis pallida* (Table 2), is the dominant species in the shrub layer. *Acacia minuata* is second in importance in the tree layer at both sites.

Species richness is markedly greater in the tree and shrub layers at La Joya. This probably reflects differences in transect lengths. The 3 transects at La Joya were each 140 m long while at Bentsen State Park each of the transects was 30 m long. The longer transects at La Joya allowed the occurrence of a greater number of uncommon to rare species, thus increasing species richness.

Guinea grass, *Panicum maximum*, was the dominant species in the ground layer at Bentsen State Park, but Guinea grass was third in importance at La Joya (Table 3). The dominant in the ground layer at La Joya was Texas virgin's bower, *Clematis drummondii.* Plains bristlegrass, *Setaria leucopila* , a native species, was the most important grass and it ranked second in importance in the ground layer.

Table 1. Comparison of species importance in the tree layer.

Species	Frequency %	Relative Frequency	Cover %	Relative Cover	Importance Value
Celtis laevigata	66.7	39.4	33.86	47.1	86.5
Acacia minuata	35.7	21.1	21.13	29.4	50.5
Celtis pallida	16.7	9.9	4.07	5.7	15.6
Salix exigua	14.3	8.5	5.00	6.9	15.4
Fraxinus berlandieriana	9.5	5.6	1.91	2.6	8.2
Ulmus crassifolia	7.1	4.2	2.02	2.8	7.0
Tamarix aphylla	4.8	2.8	1.93	2.7	5.5
Baccharis neglecta	4.8	2.8	0.83	1.2	4.0
Ehretia anacua	4.8	2.8	0.61	0.8	3.6
Salix nigra	4.8	2.8	0.60	0.8	3.6
		Total	71.96		

Table 2. Species importance in the shrub layer.

Species	Frequency %	Relative Frequency	Cover %	Relative Cover	Importance Value
Celtis pallida	28.6	15.0	1.64	9.8	24.8
Fraxinus berlandieriana	26.2	13.7	1.85	11.1	24.8
Salix exigua	14.3	7.5	2.59	15.6	23.1
Amelopsis arborea	16.7	8.8	2.34	14.1	22.9
Arundo donax	11.9	6.2	2.43	14.6	20.8
Celtis laevigata	26.2	13.7	1.13	6.8	20.5
Cocculus diversifolius	16.7	8.8	0.58	3.5	12.3
Phragmites australis	2.4	1.3	1.48	8.9	10.2
Clematis drummondii	11.9	6.2	0.55	3.3	9.5
Cissus incisa	11.9	6.2	0.26	1.6	7.8
Leucosyris spinosa	4.8	2.5	0.69	4.1	6.6
Baccharis neglecta	2.4	1.3	0.62	3.7	5.0
Ehretia anacua	7.1	3.7	0.15	0.9	4.6
Ulmus crassifolia	4.8	2.5	0.31	1.9	4.4
Ziziphus obtusifolia	2.4	1.3	0.03	0.2	1.5
Tamarix aphylla	2.4	1.3	0.01	0.1	1.4
		Total	16.66		

Table 3. Species importance in the ground layer.

Species	Freq. %	Rel. Freq.	Cover %	Rel. Cover	Importance Value
Clematis drummondii	78.6	17.35	6.84	20.55	37.90
Setaria leucopila	52.4	11.57	4.74	14.24	25.81
Panicum maximum	35.7	7.88	4.86	14.60	22.48
Pennisetumcilare	19.0	4.19	5.69	17.09	21.28
Rivina humilus	40.5	8.94	1.53	4.60	13.54
Cocculus diversifolius	31.0	6.84	1.45	4.36	11.20
Amelopsis arborea	23.8	5.25	1.54	4.63	9.88
Cissus incisa	28.6	6.31	0.55	1.65	7.96
Celtis laevigata	26.2	5.78	0.30	0.90	6.68
Cynodon dactylon	4.8	1.06	1.33	4.00	5.06
Chromolaena odorata	14.3	3.16	0.44	1.32	4.48
Celtis pallida	11.9	2.63	0.41	1.23	3.86
Matelea parviflora	14.3	3.16	0.19	0.57	3.73
Dicanthium aristatum	9.5	2.10	0.08	0.24	2.34
Heimia salicifolia	2.4	0.53	0.58	1.74	2.27
Paspalum lividum	2.4	0.53	0.52	1.56	2.09
Eriochloa punctata	2.4	0.53	0.50	1.50	2.03
Leptochloa nealleyi	4.8	1.06	0.17	0.51	1.57
Ulmus crassifolia	4.8	1.06	0.15	0.45	1.51
Fraxinus berlandieriana	4.8	1.06	0.05	0.15	1.21
Ehretia anacua	4.8	1.06	0.05	0.15	1.21
Sarcostemma cynanchoides	4.8	1.06	0.04	0.12	1.18
Teucrium cubense	4.8	1.06	0.03	0.09	1.15
Chloris cucullata	2.4	0.53	0.17	0.51	1.04
Bothriochloa laguroides	2.4	0.53	0.15	0.45	0.98
Vigna luteola	2.4	0.53	0.13	0.39	0.92
Eriocola punctata	2.4	0.53	0.10	0.30	0.83

Salix exigua	2.4	0.53	0.06	0.18	0.71
Ruellia nudiflora	2.4	0.53	0.04	0.12	0.65
Acacia minuata	2.4	0.53	0.03	0.09	0.62
Leucosyris spinosa	2.4	0.53	0.03	0.09	0.62
Solanum triquetrum	2.4	0.53	0.01	0.03	0.56

Table 3 continued.

Species	Freq. %	Rel. Freq.	Cover %	Rel. Cover	Importance Value
Melothria pendula	2.4	0.53	0.01	0.03	0.56
Arundo donax	2.4	0.53	<0.01	0.00	0.53
		Total	33.29		

Appendix 2. Mouth of the Rio Grande

21 June 2000. Cameron County, Texas. Riparian study; at the mouth of the Rio Grande. Transect 1 starts at water's edge. Spartina alterniflora is 1.21 meters tall; water depth is 9.0 cm. Avicennia germinans about 120 m from the margin of the river along a canal are about 3.0-3.5 meters tall. A red mangrove (ca 2.0 meters) tall is on the edge of the canal.

Transect 1	% cover	Rel. cover	
0-10 meters			
Spartina alterniflora	19.6	84.5	Avicennia is 39.5 cm tall near tape.
Monanthochloe littoralis	2.4	10.3	
Batis maritima	1.2	5.2	
	32.2		
10-20 meters			
Salicornia virginica	7.9	64.8	
Batis maritima	4.3	35.2	
	12.2		
20-30 meters			
Bare			
30-40 meters			
Bare			
40-50 meters			
Batis maritima	13.3	97.8	
Monanthochloe littoralis	0.3	2.2	
	13.6		
50-60 meters			
Batis maritima	41.0	79.6	
Salicornia virginica	10.3	20.0	
Monanthochloe littoralis	0.2	0.4	
	51.5		
60-70 meters			
Batis maritima	15.7		
70-80 meters			
Avicennia germinans	59.7	51.1	
Batis maritima	57.1	48.9	
	116.8		

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Avicennia is 1.9 meters tall; ca 3.0 meters from a canal-channel; in flower.

Transect 1. Summary of 8 intervals (80 meters).

	Freq.	Rel. freq.	% cover	Rel. cover	IV
Batis maritima	75.0	50.0	16.58	56.9	106.9
Avicennia germinans	12.5	8.3	7.46	25.6	33.9
Salicornia virginica	25.0	16.7	2.28	7.8	24.5
Monanthochloe littoralis	25.0	16.7	0.36	1.2	17.9
Spartina alterniflora	12.5	8.3	2.45	8.4	16.7
			23.30		

Transect 2. Avicennia is 64.0 cm tall.

	% cover	Rel. cover
0-10 meters		
Batis maritima	30.0	
10-20 meters		
Batis maritima	1.2	
20-30 meters		
Bare		
30-40 meters		
Salicornia virginica	2.3	92.0
Monanthochloe littoralis	0.2	8.0
	2.5	
40-50 meters		
Salicornia virginica	20.1	62.0
Batis maritima	12.1	37.3
Monanthochloe littoralis	0.7	3.0
	32.4	
50-60 meters		
Batis maritima	18.0	76.3
Salicornia virginica	4.9	20.8
Monanthochloe littoralis	0.7	3.0
	23.6	
60-70 meters		
Batis maritima	10.7	

70-80 meters			
Batis maritima	40.9	76.6	
Salicornia virginica	8.2	15.4	
Avicennia germinans	4.3	8.9	(Mangrove is 54.0 cm tall)
	53.4		

Transect 2. Summary. 8 intervals (80 meters).

	Freq.	Rel. freq.	% cover	Rel. cover	IV
Batis maritima	62.5	38.5	12.78	71.4	106.9
Salicornia virginica	50.0	30.8	4.44	24.8	55.6
Monanthochloe littoralis	37.5	23.1	0.14	0.8	29.9
Avicennia germinans	12.5	7.7	0.54	3.0	10.7
			17.90		

Transect 3.

	% cover	Rel. cover
0-10 meters		
Salicornia virginica	10.6	44.7
Batis maritima	7.5	31.6
Monanthochloe littoralis	4.5	19.0
Lycium carolinianum	1.1	4.6
	23.7	
10-20 meters		
Salicornia virginica	4.7	83.9
Monanthochloe littoralis	0.9	16.1
	5.6	
20-30 meters		
Batis maritima	25.2	35.3
Salicornia virginica	23.6	33.1
Monanthochloe littoralis	19.5	27.3
Suaeda linearis	2.2	3.1
Lycium carolinianum	0.9	1.3
	71.4	
30-40 meters		
Batis maritima	13.6	59.6
Salicornia virginica	9.2	40.4
	22.8	

40-50 meters		
Salicornia virginica	15.0	65.8
Suaeda linearis	6.1	26.8
Batis maritima	1.0	4.4
Monanthochloe littoralis	0.7	3.1
	22.8	
50-60 meters		
Batis maritima	43.1	80.1
Salicornia virginica	10.6	19.7
Lycium carolinianum	0.1	0.2
	53.8	
60-70 meters		
Batis maritima	35.6	90.1
Salicornia virginica	3.7	9.4
Monanthochloe littoralis	0.2	0.5
	39.5	
70-80 meters		
Batis maritima	3.2	

Transect 3. Summary of 8 intervals (80 meters).

	Freq.	Rel. freq.	% cover	Rel.cover	IV
Batis maritima	87.5	29.2	16.15	53.2	82.4
Salicornia virginica	87.5	29.2	9.68	31.9	61.1
Monanthochloe littoralis	62.5	20.8	3.23	10.6	31.4
Lycium carolinianum	37.5	12.5	0.26	0.9	13.4
Suaeda linearis	25.0	8.3	1.04	3.4	11.7
			30.36		

Summary of 3 transects. 8 intervals x 3 transects = 24 intervals.

Batis maritima	75.0	36.7	15.17	58.8	95.5
Salicornia virginica	54.2	26.5	5.46	21.2	47.7
Monanthochloe littoralis	41.7	20.4	1.24	4.8	25.2
Avicennia germinans	8.3	4.1	2.67	10.3	14.4
Lycium carolinianum	12.5	6.1	0.09	0.3	6.4
Suaeda linearis	8.3	4.1	0.35	1.3	5.4
Spartina alterniflora	4.2	2.0	0.82	3.2	5.2
			25.8		

Appendix 2. Palmito Pumphouse

27 June 2000. Palmitto Pumphouse. Riparian vegetation. Southeast of Brownsville near Highway 4. Cameron County, Texas.

Transect 1

Ground layer

0-10 meters	% cover	Rel. cover
Monanthochloe littoralis	17.1	42.0
Sporobolous virginicus	12.7	31.2
Maytenus phyllanthoides	4.7	11.5
Prosopis reptans	2.5	6.1
Celtis pallida	2.2	5.4
Panicum repens	1.5	3.7
	40.7	

Shrub layer

Celtis pallida	19.4	52.7
Phragmites australis	11.3	30.7
Ziziphus obtusifolia	6.1	16.6
	36.8	

Shrub heights

Phragmites australis	2.6 m
Ziziphus obtusifolia	2.0 m
Celtis pallida	2.1 m

NO TREES

....

10-20 meters

Ground layer

Panicum maximum	11.7	81.3
Acleisanthes obtusa	2.7	18.8
	14.4	

Shrub layer

Phaulothamnus spinescens	63.9	86.0
Ziziphus obtusifolia	9.9	13.3
Celtis pallida	0.5	0.7
	74.3	

Shrub heights

Phaulothamnus spinescens	2.8 m
Celtis pallida	2.25 m
Ziziphus obtusifolia	1.9 m

Tree layer

Prosopis glandulosa	31.0	Tree height: 3.9 m

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20-30 meters

Ground layer

Panicum maximum	35.9	62.9
Maytenus phyllanthoides	6.6	11.6
Monanthochloe littoralis	6.4	11.2
Prosopis reptans	3.2	5.6
Bastardia viscosa	1.9	3.3
Celtis pallida	1.1	1.9
Prosopis glandulosa	1.0	1.8
Borrichia frutescens	1.0	1.8
	57.1	

Shrub layer

Celtis pallida	21.5	91.9
Opuntia engelmannii	1.9	8.1
	23.4	

Shrub heights

Celtis pallida	1.8 m
Opuntia engelmannii	1.2 m

Tree layer

Prosopis glandulosa 29.0 % cover …. Tree height=3.9 meters

……………………………………………………………………………

Transect 1. Ground layer. Summary. 30 meters.

	Freq.	Rel. freq.	% cover	Rel. cover	IV
Panicum maximum	66.7	12.5	15.87	42.4	54.9
Monanthochloe littoralis	66.7	12.5	7.83	20.9	33.4
Maytenus phyllanthoides	66.7	12.5	3.77	10.1	22.6
Sporobolus virginicus	33.3	6.3	4.23	11.3	17.6
Prosopis reptans	66.7	12.5	1.90	5.1	17.6
Celtis pallida	66.7	12.5	1.10	2.9	15.4
Acleisanthes obtusa	33.3	6.3	0.90	2.4	8.7
Bastardia viscosa	33.3	6.3	0.63	1.7	8.0
Panicum repens	33.3	6.3	0.50	1.3	7.6
Prosopis glandulosa	33.3	6.3	0.33	0.9	7.2
Borrichia frutescens	33.3	6.3	0.33	0.9	7.2
			37.39		

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Transect 1. Shrub layer. Summary. 30 meters.

Celtis pallida	100.0	37.5	13.80	30.8	68.3
Phaulothamnus spinescens	33.3	12.5	21.30	47.5	60.0
Ziziphus obtusifolia	66.7	25.0	5.33	11.9	36.9

Phragmites australis	33.3	12.5	3.77	8.4	20.9
Opuntia engelmannii	33.3	12.5	0.63	1.4	13.9
			44.83		

Shrub density and height (m) in Transect 1

Phragmites australis (colony)	2.6 m
Ziziphus obtusifolia (2)	2.0 m, 1.9
Celtis pallida (3)	2.1 m, 2.25 m,1.8 m
Phaulothamnus spinescens (1)	2.8 m
Opuntia engelmannii (1)	1.2 m

7 shrubs

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Transect 1. Tree layer. Summary. 30 meters.

Prosopis glandulosa 20.0

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Tree density and height (m) in Transect 1

Prosopis glandulosa (2) 3.9, 3.9

Transect 2.

Ground layer

0-10 meters

Monanthochloe littoralis	13.8	31.0
Panicum maximum	11.9	26.7
Maytenus phyllanthoides	5.6	12.6
Prosopis reptans	4.5	10.1
Borrichia frutescens	3.6	8.1
Acleisanthes obtusa	2.5	5.6
Sporobolus virginicus	1.9	4.3
Opuntia engelmannii	0.4	0.9
Sporobolus pyramidatus	0.2	0.4
Setaria leucopila	0.1	0.2
	44.5	

Shrub layer

Phaulothamnus spinescens	12.8	39.8
Prosopis glandulosa	10.0	31.1
Phragmites australis	7.8	24.2
Zanthoxylum fagara	1.6	5.0
	32.2	

Shrub heights

Prosopis glandulosa	2.2 m, 2.0 m
Phaulothamnus spinescens	1.8 m
Zanthoxylum fagara	1.45 m
Phragmites australis	2.9 m

NO Trees

Appendix 2. Palmito Pumphouse

10-20 meters

Ground layer

Panicum maximum	65.5	98.3
Maytenus phyllanthoides	1.1	1.7
	66.6	

Shrub layer

Zanthoxylum fagara	27.7	98.2
Celtis pallida	0.5	1.8
	28.2	

Shrub heights

Zanthoxylum fagara 2.4 m, 2.0 m, 2.15 m

Tree layer

Prosopis glandulosa	83.0	91.6
Celtis pallida	7.6	8.4
	90.6	

Tree heights

Prosopis glandulosa 4.4 m, 4.0 m, 3.6 m, 3.5 m

Celtis pallida 3.1 m

20-30 meters

Ground layer

Panicum maximum	33.8	47.7
Maytenus phyllanthoides	30.5	43.1
Monanthochloe littoralis	2.7	3.8
Prosopis reptans	2.2	3.1
Prosopis glandulosa	1.4	2.0
Cynanchum barbigera	2.2	0.3
	70.8	

Shrub layer

Opuntia engelmannii	17.8	42.3
Phaulothamnus spinescens	11.8	28.0
Zanthoxylum fagara	6.5	15.4
Prosopis glandulosa	5.5	13.1
Acanthocereus pentagonus	0.5	1.2
	42.1	

Shrub heights

Prosopis glandulosa	1.25 m	Zanthoxylum fagara	2.2 m
Opuntia engelmannii	0.65 m	Phaulothamnus spinescens	1.95 m

Appendix 2. Palmito Pumphouse

Tree layer

Prosopis glandulosa 28.5 % cover height: 3.7 m

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Transect 2. Ground layer. Summary. 30 meters.

Panicum maximum	100.0	16.7	37.07	61.1	77.8
Maytenus phyllanthoides	100.0	16.7	12.40	20.5	37.2
Monanthochloe littoralis	66.7	11.1	5.50	9.1	20.2
Prosopis reptans	66.7	11.1	2.23	3.7	14.8
Borrichia frutescens	33.3	5.6	1.20	2.0	7.6
Acleisanthes obtusa	33.3	5.6	0.83	1.4	7.0
Sporobolus virginicus	33.3	5.6	0.63	1.0	6.6
Prosopis glandulosa	33.3	5.6	0.47	0.8	6.4
Opuntia engelmannii	33.3	5.6	0.13	0.2	5.8
Sporobolus pyramidatus	33.3	5.6	0.07	0.1	5.7
Cynanchum barbigerum	33.3	5.6	0.07	0.1	5.7
Setaria leucopila	33.3	5.6	0.03	0.1	5.7
			60.63		

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Shrub layer. Summary of Transect 2

Zanthoxylum fagara	100.0	27.3	11.93	34.9	62.2
Phaulothamnus spinescens	66.7	18.2	8.20	24.0	42.2
Prosopis glandulosa	66.7	18.2	5.17	15.1	33.3
Opuntia engelmannii	33.3	9.1	5.93	17.4	26.5
Phragmites australis	33.3	9.1	2.60	7.6	16.7
Celtis pallida	33.3	9.1	0.17	0.5	9.6
Acanthocereus pentagonus	33.3	9.1	0.17	0.5	9.6
			34.17		

Shrub density and heights

Prosopis glandulosa (3)	2.2 m, 2.0 m, 1.25 m
Phaulothamnus spinescens (2)	1.8 m, 1.95 m
Zanthoxylum fagara (5)	1.45 m, 2.4 m, 2.0 m, 2.15 m, 2.2 m
Phragmites australis	2.9 m
Opuntia engelmannii	0.65 m

Tree layer. Summary of Transect 2

Prosopis glandulosa	66.7	66.7	37.17	93.6	160.3
Celtis pallida	33.3	33.3	2.53	6.4	39.7
			39.70		

Tree density and heights in Transect 2

Prosopis glandulosa (5)	4.0 m, 3.6 m, 3.5 m, 3.7 m, 4.4 m
Celtis pallida (1)	3.1 m

Transect 3. River bank is collapsing at this site; mesquite is leaning over the river.

0-10 meters

Ground layer

Sporobolus virginicus	22.1	54.8
Maytenus phyllanthoides	5.8	14.4
Ziziphus obtusifolia	4.9	12.2
Tridens eragrostoides	2.1	5.2
Monanthochloe littoralis	1.4	3.5
Zanthoxylum fagara	1.1	2.7
Prosopis reptans	0.9	2.2
Borrichia frutescens	0.7	1.7
Unident. grass	0.7	1.7
Opuntia leptocaulis	0.6	1.5
	40.3	

Shrub layer

Opuntia engelmannii	10.5	38.5
Acanthocereus pentagonus	5.6	20.5
Yucca treculeana	4.8	17.6
Zanthoxylum fagara	4.2	15.4
Ziziphus obtusifolia	2.2	8.1
	27.3	

Shrub heights

Ziziphus obtusifolia	1.0 m
Opuntia engelmannii	1.05 m
Acanthocereus pentagonus	0.60 m
Yucca treculeana	0.45 m
Zanthoxylum fagara	1.5 m

Trees

Prosopis glandulosa	16.0 % cover	height: 3.4 m

10-20 meters

Ground layer

Maytenus phyllanthoides	13.4	57.8
Setaria leucopila	3.5	15.1
Prosopis reptans	1.9	8.2
Opuntia leptocaulis	1.1	4.7
Tridens eragrostoides	1.1	4.7
Malvastrum americanum	1.0	4.3
Cynanchum barbigerum	0.6	2.6
Borrichia frutescens	0.4	1.7
Monanthochloe littoralis	0.2	0.9
	23.2	

Shrub layer			Shrub height
Phaulothamnus spinescens	32.0	44.6	1.9 m
Zanthoxylum fagara	27.2	37.9	1.5 m, 1.4 m
Celtis pallida	8.2	11.4	1.55 m
Acanthocereus pentagonus	4.3	6.0	0.80 m
	71.7		

Tree layer			Tree height
Prosopis glandulosa	5.0 % cover		3.3 m

20-30 meters

Ground layer		
Setaria leucopila	14.2	28.5
Sporobolus virginicus	9.1	18.3
Maytenus phyllanthoides	8.6	17.3
Trixis inula	6.7	13.5
Borrichia frutescens	5.5	11.0
Pappophorum vaginatum	4.3	8.6
Prosopis reptans	1.1	2.2
Cynanchum barbigerum	0.3	0.6
	49.8	

Shrub layer			Shrub height
Forestiera angustifolia	27.3	76.3	1.7 m
Opuntia engelmannii	8.5	23.7	1.15 m
	35.8		

NO trees

....

Transect 3. Summary. 30 meters.

Ground layer

Maytenus phyllanthoides	100.0	11.1	9.27	23.5	34.6
Sporobolus virginicus	66.7	7.4	10.40	26.4	33.8
Setaria leucopila	66.7	7.4	5.90	15.0	22.4
Borrichia frutescens	100.0	11.1	2.20	5.6	16.7
Prosopis reptans	100.0	11.1	1.30	3.3	14.4
Pappophorum vaginatum	33.3	3.7	3.03	7.7	11.4
Tridens eragrostoides	66.7	7.4	1.07	2.7	10.1
Trixis inula	33.3	3.7	2.23	5.7	9.4
Opuntia leptocaulis	66.7	7.4	0.57	1.4	8.8
Monanthochloe littoralis	66.7	7.4	0.53	1.4	8.8
Cynanchum barbigerum	66.7	7.4	0.30	0.8	8.2
Ziziphus obtusifolia	33.3	3.7	1.63	4.1	7.8
Zanthoxylum fagara	33.3	3.7	0.37	0.9	4.6

Malvastrum americanum	33.3	3.7	0.33	0.8	4.5
Unident. grass	33.3	3.7	0.23	0.6	4.3
			39.36		

Shrub layer. Summary. 30 meters.

Zanthoxylum fagara	66.7	18.2	10.47	23.3	41.5
Phaulothamnus spinescens	33.3	9.1	10.67	23.7	32.8
Opuntia engelmannii	66.7	18.2	6.33	14.1	32.3
Forestiera angustifolia	33.3	9.1	9.10	20.3	29.4
Acanthocereus pentagonus	66.7	18.2	3.30	7.3	25.5
Celtis pallida	33.3	9.1	2.73	6.1	15.2
Yucca treculeana	33.3	9.1	1.60	3.6	12.7
Ziziphus obtusifolia	33.3	9.1	0.73	1.6	10.7
			44.93		

Shrub density and heights in Transect 3

Ziziphus obtusifolia (1)	1.0 m
Opuntia engelmannii	1.05 m, 1.15 m
Acanthocereus pentagonus (2)	0.60 m, 0.80 m
Yucca treculeana (1)	0.45 m
Zanthoxylum fagara (3)	1.5 m, 1.5 m, 1.4 m
Celtis pallida (1)	1.55 m
Phaulothamnus spinescens (1)	1.9 m
Forestiera angustifolia (1)	1.7 m

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Tree layer. Summary. 30 meters.

Prosopis glandulosa Freq. = 66.7 % cover = 21.0 height: 3.3 m, 3.4 m

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Summary of 3 transects at Palmitto Pumphouse. Pooled data represents 90 meters.

Ground layer

Panicum maximum	55.6	8.2	17.64	38.5	46.7
Maytenus phyllanthoides	88.9	13.1	8.48	18.5	31.6
Monanthochloe littoralis	66.7	9.8	4.62	10.1	19.9
Sporobolus virginicus	44.4	6.6	5.09	11.1	17.7
Prosopis reptans	77.8	11.5	1.81	4.0	15.5
Borrichia frutescens	55.6	8.2	1.24	2.7	10.9
Setaria leucopila	33.3	4.9	1.98	4.3	9.2
Cynanchum barbigerum	33.3	4.9	0.12	0.3	5.2
Acleisanthes obtusa	22.2	3.3	0.58	1.3	4.7
Celtis pallida	22.2	3.3	0.37	0.8	4.1
Tridens eragrostoides	22.2	3.3	0.36	0.8	4.1
Prosopis glandulosa	22.2	3.3	0.27	0.6	3.9
Pappophorum vaginatum	11.1	1.6	1.01	2.2	3.8
Opuntia leptocaulis	22.2	3.3	0.19	0.4	3.7
Trixis inula	11.1	1.6	0.74	1.6	3.2
Ziziphus obtusifolia	11.1	1.6	0.54	1.2	2.8

Bastardia viscosa	11.1	1.6	0.21	0.5	2.1
Panicum repens	11.1	1.6	0.17	0.4	2.0
Zanthoxylum fagara	11.1	1.6	0.12	0.3	1.9
Unident. grass	11.1	1.6	0.08	0.2	1.8
Malvastrum americanum	11.1	1.6	0.11	0.2	1.8
Opuntia engelmannii	11.1	1.6	0.04	0.1	1.7
Sporobolus pyramidatus	11.1	1.6	0.02	< 0.1	1.6
			45.79		
Shrub layer. Pooled data for 3 transects (90 meters)					
Phaulothamnus spinescens	44.4	13.3	13.39	31.1	44.4
Zanthoxylum fagara	55.6	16.7	7.47	17.3	34.0
Celtis pallida	55.6	16.7	5.57	12.9	29.6
Opuntia engelmannii	44.4	13.3	4.30	10.0	23.3
Ziziphus obtusifolia	33.3	10.0	3.80	8.8	18.8
Acanthocereus pentagonus	33.3	10.0	1.16	2.7	12.7
Phragmites australis	22.2	6.7	2.12	4.9	11.6
Prosopis glandulosa	22.2	6.7	1.72	4.0	10.7
Forestiera angustifolia	11.1	3.3	3.03	7.0	10.3
Yucca treculeana	11.1	3.3	0.53	1.2	4.5
			43.09		
Tree layer. Pooled data for 3 transects (90 meters)					
Prosopis glandulosa	66.7	85.7	21.39	96.2	181.9
Celtis pallida	11.1	14.3	0.84	3.8	18.1
			22.23		

27 June 2000. Audubon Sabal Palm Sanctuary. Cameron County. Southeast of Brownsville. Cameron County, Texas. The site has many dead Celtis laevigata trees.

Transect 1

0-10 meters

Ground layer	% cover	Rel. cover	
Panicum maximum	69.6	87.7	
Panicum hirsutum	8.1	10.2	
Rubus riograndis	1.2	1.5	
Vigna luteola	0.5	0.6	
	79.4		
Shrub layer			
Phragmites australis	11.5	height: (colony) = 4.0 m	
Tree layer			
Fraxinus berlandieriana	17.0	58.6	height: 7.5 m
Celtis laevigata	12.0	41.4	height: 4.5 m

....

10-20 meters

Ground layer			
Panicum maximum	54.1	60.3	
Cenchrus ciliaris	23.4	26.1	
Chiococca alba	12.2	13.6	
	89.7		
Shrub layer			
Celtis laevigata	2.0		height: 1.2 m
Tree layer			
Celtis laevigata	84.0	69.4	height: 3.0 m, 6.0 m, 8.0 m
Fraxinus berlandieriana	37.0	30.6	height: 7.5 m
	121.0		

....

20-30 meters

Ground layer			
Panicum maximum	70.1	64.3	
Chiococca alba	38.4	35.2	
Sabal mexicana	0.5	0.5	
	109.0		
NO Shrub layer			
Tree layer			
Celtis laevigata	100.0	74.6	height: 8.0 m

Leucaena pulverulenta	34.0	25.4	height: 8.5 m

....

30-40 meters

Ground layer

Panicum maximum	100.0	99.7
Cocculus diversifolius	0.3	0.3
	100.3	

NO shrub layer

Tree layer

Celtis laevigata	67.0	height: 8.5 m, 9.0 m

....

40-50 meters

Ground layer

Panicum maximum	100.0	99.8
Cocculus diversifolius	0.2	0.2
	100.2	

NO shrub layer

Tree layer

Celtis laevigata	61.0	height: 6.0 m

....

Transect 1. Summary. (50 meters).

Ground layer	Freq.	Rel. freq.	% cover	Rel. cover	IV

Panicum maximum	100.0	35.7	78.76	82.3	118.0
Chiococca alba	40.0	14.3	10.12	10.6	24.9
Cocculus diversifolius	40.0	14.3	0.10	0.1	14.3
Cenchrus ciliaris	20.0	7.1	4.68	4.9	12.0
Panicum hirsutum	20.0	7.1	1.62	1.7	8.8
Rubus riograndis	20.0	7.1	0.24	0.3	7.4
Vigna luteola	20.0	7.1	0.10	0.1	7.2
Sabal mexicana	20.0	7.1	0.10	0.1	7.2
			95.72		

Shrub layer					
Phragmites australis	20.0	50.0	2.30	85.2	135.2
Celtis laevigata	20.0	50.0	0.40	14.8	64.8
			2.70		

Shrub heights

Phragmites australis	4.0 m
Celtis laevigata	1.2 m

Tree layer					
Celtis laevigata	100.0	62.5	64.80	78.6	141.1
Fraxinus berlandieriana	40.0	25.0	10.80	13.1	38.1
Leucaena pulverulenta	20.0	12.5	6.80	8.3	20.8
			82.40		

Tree heights

Celtis laevigata (8)	4.5 m, 3.0 m, 6.0 m, 8.0 m, 8.0 m, 8.5 m, 9.0 m, 6.0 m
Fraxinus berlandieriana (2)	7.5 m, 7.5 m
Leucaena pulverulenta (1)	8.5 m

Transect 2.

0-10 meters

Ground layer

Panicum maximum	74.7	85.9
Cenchrus ciliaris	7.5	8.6
Ampelopsis arborea	4.8	5.5
	87.0	

Shrub layer

Phragmites australis	6.0	75.0	height: 2.8 m
Mimosa asperata	2.0	25.0	height: 1.9 m
	8.0		

Tree layer

Leucaena pulverulenta	30.0	height: 6.5 m

……………………………………………………………………………..

10-20 meters
Ground layer

Panicum maximum	100.0		

NO shrub layer

Tree layer

Leucaena pulverulenta	44.5	42.6	height: 7.0 m, 6.5 m
Parkinsonia aculeata	30.0	28.7	height: 5.5 m
Celtis laevigata	25.0	23.9	height: 7.1 m
Sabal mexicana	5.0	4.8	height: 8.0 m
	104.5		

....

20-30 meters
Ground layer

Panicum maximum	100.0	

NO shrub layer

Tree layer

Sabal mexicana	40.0	height: 8.0 m

....

30-40 meters
Ground layer

Panicum maximum	100.0	many large, dead hackberries

NO shrub layer

NO tree layer

....

40-50 meters
Ground layer

Panicum maximum	100.0	

Shrub layer (base of levee)

Arundo donax	12.0	height: 3.5 m

....

Transect 2. Summary. 50 meters.
Ground layer

Panicum maximum	100.0	71.4	94.44	97.5	168.9
Cenchrus ciliaris	20.0	14.3	1.50	1.5	15.8
Ampelopsis arborea	20.0	14.3	0.96	1.0	15.3
			96.90		

Shrub layer						
Arundo donax	20.0	33.3	2.40	60.0	93.3	height: 2.8 m
Phragmites australis	20.0	33.3	1.20	30.0	63.3	height: 1.9 m
Mimosa asperata	20.0	33.3	0.40	10.0	43.3	height: 3.5 m
			4.00			
Tree layer						
Leucaena pulverulenta	40.0	33.3	14.90	42.7	76.0	
Sabal mexicana	40.0	33.3	9.00	25.8	59.1	
Parkinsonia aculeata	20.0	16.7	6.00	17.2	33.9	
Celtis laevigata	20.0	16.7	5.00	14.3	31.0	
			34.90			

Tree heights

Leucaena pulverulenta	6.5 m, 7.0 m, 6.5 m
Parkinsonia aculeata	5.5 m
Celtis laevigata	7.1 m
Sabal mexicana	8.0 m, 8.0 m

Transect 3.

0-10 meters

Ground layer			
Panicum maximum	84.2	95.4	
Mikania scandens	4.1	4.6	
	88.3		
Shrub layer			
Phragmites australis	10.5		height: 3.0 m
Tree layer			
Acacia minuata	52.0		height: 6.1 m

....

10-20 meters

Panicum maximum	91.7		
Shrub layer			
Celtis laevigata	31.0	64.6	height: 2.5 m
Zanthoxylum fagara	17.0	35.4	height: 2.6 m
Tree layer			
Celtis laevigata	45.0	81.8	height: 4.0 m, 8.0 m
Acacia minuata	10.0	18.2	height: 6.1 m

....

20-30 meters
Ground layer

Panicum maximum	100.0		

NO shrub layer

Tree layer

Celtis laevigata	30.0		height: 8.0 m

....

30-40 meters
Ground layer

Panicum maximum	100.0		

NO shrub layer

NO tree layer

....

40-50 meters
Ground layer

Panicum maximum	98.0	98.3	
Chiococca alba	1.7	1.7	
	99.7		

Shrub layer

Arundo donax	18.0		height: 3.5 m

NO tree layer

Transect 3. Summary. 50 meters.

Ground layer						
Panicum maximum	100.0	71.4	94.78	98.8	170.2	
Mikania scandens	20.0	14.3	0.82	0.9	15.2	
Chiococca alba	20.0	14.3	0.34	0.4	14.7	
			95.94			
Shrub layer						
Celtis laevigata	20.0	25.0	6.20	40.5	65.5	height: 2.5 m
Arundo donax	20.0	25.0	3.60	23.5	48.5	height: 3.5 m
Zanthoxylum fagara	20.0	25.0	3.40	22.2	47.2	height: 2.6 m
Phragmites australis	20.0	25.0	2.10	13.7	38.7	height: 3.0 m
			15.30			
Tree layer						
Celtis laevigata	40.0	50.0	15.00	54.7	104.7	height:4.0 m, 8.0 m, 8.0 m
Acacia minuata	40.0	50.0	12.40	45.3	95.3	height: 6.1 m, 6.1 m

Sabal Palm Sanctuary. Pooled data. 15 intervals = 3 transects = 150 meters.

Ground layer					
Panicum maximum	100.0	55.6	89.33	92.9	148.5
Chiococca alba	13.3	7.4	3.49	3.6	11.0
Cenchrus ciliaris	13.3	7.4	2.06	2.1	9.5
Cocculus diversifolius	13.3	7.4	0.03	<0.1	7.4
Panicum hirsutum	6.7	3.7	0.54	0.6	4.3
Ampelopsis arborea	6.7	3.7	0.32	0.3	4.0
Mikania scandens	6.7	3.7	0.27	0.3	4.0
Rubus riograndis	6.7	3.7	0.08	0.1	3.8
Sabal mexicana	6.7	3.7	0.03	<0.1	3.7
Vigna luteola	6.7	3.7	0.03	<0.1	3.7
			96.18		
Shrub layer					
Phragmites australis	20.0	33.3	1.87	25.5	58.8
Celtis laevigata	13.3	22.2	2.20	30.0	52.2
Arundo donax	13.3	22.2	2.00	27.3	49.5
Zanthoxylum fagara	6.7	11.1	1.13	15.5	37.7
Mimosa asperata	6.7	11.1	0.13	1.8	12.9
			7.33		

Shrub heights (m)

Phragmites australis	4.0, 2.8, 3.0
Celtis laevigata (2)	1.2, 2.5
Mimosa asperata (1)	1.9
Arundo donax	3.5, 3.5, 3.5
Zanthoxylum fagara (1)	2.6

Tree layer					
Celtis laevigata	53.3	44.4	28.27	58.6	103.0
Leucaena pulverulenta	20.0	16.7	7.23	15.0	31.7
Acacia minuata	13.3	11.1	4.13	8.6	19.7
Fraxinus berlandieriana	13.3	11.1	3.60	7.5	18.6
Sabal mexicana	13.3	11.1	3.00	6.2	17.3
Parkinsonia aculeata	6.7	5.6	2.00	4.1	9.7
			48.23		

Tree heights (m)

Celtis laevigata (12)	7.1, 4.0, 8.0, 8.0, 4.5, 3.0, 6.0, 8.0, 8.0, 8.5, 9.0, 6.0
Fraxinus berlandieriana (2)	7.5, 7.5
Leucaena pulverulenta (4)	8.5, 6.5, 7.0, 6.5
Parkinsonia aculeata (1)	5.5
Sabal mexicana (2)	8.0, 8.0
Acacia minuata (2)	6.1, 6.1

Appendix 2. Salineño

9 November 2000. Riparian vegetation at Salineño. Starr County, Texas.
Transect 1

Ground layer	% cover	Rel. cover
0-10 meters (from the margin of the Rio Grande)		
Paspalum lividum	43.9	73.4
Paspalum virgatum	4.9	8.2
Ruellia nudiflora	2	3.3
Symphyotrichum subulatum	1.9	3.2
Celtis laevigata	1.9	3.2
Dichanthium aristatum	1.6	2.7
Ipomoea amnicola	1.5	2.5
Calyptocarpus vialis	0.6	1
Cynodon dactylon	0.4	0.7
Commelina erecta	0.4	0.7
Cyperus sp.	0.4	0.7
Ciclospermum leptophyllum	0.3	0.5
	59.8	
10-20 meters		
Dichanthium annulatum	10.4	20.6
Mirabilis jalapa	10.4	20.6
Paspalum virgatum	10.3	20.4
Clematis drummondii	6	11.9
Celtis pallida	2.9	5.8
Setaria leucopila	2.8	5.6
Cyphomeris crassifolia	2.3	4.6
Celtis laevigata	0.9	1.8
Ruellia nudiflora	0.8	1.6
Ipomoea amnicola	0.8	1.6
Unident. dicot seedling	0.7	1.4
Dichanthium aristatum	0.6	1.2
Prosopis glandulosa	0.6	1.2
Cocculus diversifolius	0.6	1.2
Cynodon dactylon	0.3	0.6
	50.4	
20-30 meters		
Clematis drummondii	15.8	54.9
Mirabilis jalapa	8	27.8
Unident. dicot	2.3	8
Malvastrum coromandelianum	1.1	3.8
Cocculus diversifolius	0.5	1.7
Physalis sp.	0.5	1.7
	28.8	
30-40 meters		
Cenchrus ciliaris	29	61.4
Ruellia nudiflora	8.1	17.2
Mirabilis jalapa	4.3	9.1
Physalis sp.	2.8	5.9
Setaria leucopila	0.9	1.9
Celtis pallida	0.9	1.9
Malvastrum coromandelianum	0.9	1.9
Solanum triquetrum	0.3	0.6
	47.2	

Appendix 2. Salineño

Shrub layer		
0-10 meters		
NO SHRUBS		
10-20 meters		
Celtis laevigata	25.5	54.7
Celtis pallida	20.5	44
Cocculus diversifolius (woody)	0.6	1.3
	46.6	
20-30 meters		
Celtis pallida	83.5	81.1
Celtis laevigata	14.5	14.1
Opuntia engelmannii	5	4.9
	103	
30-40 meters		
Opuntia engelmannii	52.9	52.9
Celtis pallida	47.1	47.1
	100	
Tree layer		
0-10 meters		
Fraxinus berlandieriana	87	87.9
Acacia minuata	12	12.1
	99	
10-20 meters		
Celtis laevigata	31	44.9
Fraxinus berlandieriana	25	36.2
Celtis pallida	13	18.8
	69	
20-30 meters		
Prosopis glandulosa	30	71.4
Celtis laevigata	12	28.6
	42	
30-40 meters		
Prosopis glandulosa	100	

Transect 1. Summary. 40 meters

	Freq.	Rel. freq.	% Cover	Rel. cover	IV
Ground layer					
Paspalum lividum	25	2.4	10.98	23.7	26.1
Mirabilis jalapa	75	7.3	5.68	12.2	19.5
Cenchrus ciliaris	25	2.4	7.25	15.6	18
Clematis drummondii	50	4.9	5.45	11.7	16.6
Ruellia nudiflora	75	7.3	2.73	5.9	13.2
Paspalum virgatum	50	4.9	3.8	8.2	13.1
Dichanthium annulatum	25	2.4	2.6	5.6	8
Setaria leucopila	50	4.9	0.93	2	6.9
Celtis pallida	50	4.9	0.95	2	6.9
Physalis sp.	50	4.9	0.83	1.8	6.7
Celtis laevigata	50	4.9	0.7	1.5	6.4
Dichanthium aristatum	50	4.9	0.55	1.2	6.1
Ipomoea amnicola	50	4.9	0.58	1.2	6.1

Appendix 2. Salineño

Malvastrum coromandelianum	50	4.9	0.5	1.1	6
Cocculus diversifolius	50	4.9	0.28	0.6	5.5
Unident. dicot	25	2.4	0.58	1.2	3.6
Cyphomeris crassifolia	25	2.4	0.58	1.2	3.6
Symphyotrichium subulatum	25	2.4	0.48	1	3.4
Unident. dicot seedling	25	2.4	0.18	0.4	2.8
Calyptocarpus vialis	25	2.4	0.15	0.3	2.7
Commelina erecta	25	2.4	0.1	0.2	2.6
Solanum triquetrum	25	2.4	0.08	0.2	2.6
Ciclospermum leptophyllum	25	2.4	0.08	0.2	2.6
Cyperus sp.	25	2.4	0.1	0.2	2.6
Prosopis glandulosa	25	2.4	0.15	0.3	2.7
			46.47		
Shrub layer. Summary. Transect 1					
Celtis pallida	75	37.5	37.78	60.5	98
Opuntia engelmannii	50	25	14.48	23.2	48.2
Celtis laevigata	50	25	10	16	41
Cocculus diversifolius	25	12.5	0.15	0.2	12.7
			62.41		
Tree layer. Summary. Transect 1					
Prosopis glandulosa	50	25	32.5	41.9	66.9
Fraxinus berlandieriana	50	25	28	36.1	61.1
Celtis laevigata	50	25	10.75	13.9	38.9
Celtis pallida	25	12.5	3.25	4.2	16.7
Acacia minuata	25	12.5	3	3.9	16.4
			77.5		

Transect 2. 10 meters upriver from Transect 1.

Ground layer	% cover	Rel. cover
0-10 meters		
Paspalum lividum	25.2	42.6
Cynodon dactylon	15.7	26.5
Eriochloa punctata	6.6	11.1
Ipomoea amnicola	5.1	8.6
Cyperus sp.	2.2	3.7
Ruellia nudiflora	1.5	2.5
Commelina erecta	1	1.7
Celtis laevigata	0.7	1.2
Unident. grass	0.4	0.7
Polygonum sp.	0.4	0.7
Eclipta prostrata	0.2	0.3
Paspalum virgatum	0.2	0.3
	59.2	
10-20 meters		
Clematis drummondii	8.9	28.3
Mirabilis jalapa	7.6	24.2
Celtis pallida	5	15.9
Paspalum virgatum	3.7	11.8
Ruellia nudiflora	3.4	10.8
Cocculus diversifolius	1.2	3.8
Acacia minuata	0.6	1.9
Celtis laevigata	0.5	1.6

Appendix 2. Salineño

Malvastrum coromandelianum	0.4	1.3
Fraxinus berlandieriana	<u>0.1</u>	0.3
	31.4	
20-30 meters		
Clematis drummondii	9.9	36.3
Mirabilis jalapa	5.6	20.5
Calyptocarpus vialis	4.1	15
Rhynchosida physocalyx	1.6	5.9
Solanum triquetrum	1.4	5.1
Celtis pallida	1.2	4.4
Ruellia nudiflora	1.1	4
Malvastrum coromandelianum	1	3.7
Setaria leucopila	0.7	2.6
Physalis sp.	0.5	1.8
Melothria pendula	<u>0.2</u>	0.7
	27.3	
30-40 meters		
Cenchrus ciliaris	45	92.2
Mirabilis jalapa	<u>3.8</u>	7.8
	48.8	
Shrub layer		
0-10 meters		
Acacia minuata	0.6	
10-20 meters		
Celtis pallida	13.9	83.7
Celtis laevigata	<u>2.7</u>	16.3
	16.6	
20-30 meters		
Celtis pallida	65	81.4
Opuntia engelmannii	<u>14.9</u>	18.6
	79.9	
30-40 meters		
Celtis pallida	19.3	66.1
Opuntia engelmannii	<u>9.9</u>	33.9
	29.2	
Tree layer		
0-10 meters		
Fraxinus berlandieriana	56	
10-20 meters		
Celtis laevigata	87.5	49.6
Parkinsonia aculeata	50	28.3
Fraxinus berlandieriana	22	12.5
Prosopis glandulosa	<u>17</u>	9.6
	176.5	
20-30 meters		
Prosopis glandulosa	100	97.6
Celtis pallida	2.5	2.4
	102.5	
30-40 meters		
Prosopis glandulosa	62	

Appendix 2. Salineño

Transect 2. Summary. 40 meters

Ground layer	Freq.	Rel. freq.	% cover	Rel. cover	IV
Cenchrus ciliaris	25	3	11.25	27.2	30.2
Mirabilis jalapa	75	9.1	4.25	10.3	19.4
Paspalum lividum	25	3	6.3	15.2	18.2
Clematis drummondii	50	6.1	4.7	11.4	17.5
Ruellia nudiflora	75	9.1	1.5	3.6	12.7
Cynodon dactylon	25	3	3.93	9.5	12.5
Celtis pallida	50	6.1	1.55	3.7	9.8
Paspalum virgatum	50	6.1	0.98	2.4	8.5
Eriochloa punctata	25	3	1.65	4	7
Malvastrum coromandelianum	50	6.1	0.35	0.8	6.9
Ipomoea amnicola	25	3	1.28	3.1	6.1
Calyptocarpus vialis	25	3	1.03	2.5	5.5
Cyperus sp.	25	3	0.55	1.3	4.3
Rhynchosida physocalyx	25	3	0.4	1	4
Solanum triquetrum	25	3	0.35	0.8	3.8
Cocculus diversifolius	25	3	0.3	0.7	3.7
Commelina erecta	25	3	0.25	0.6	3.6
Acacia minuata	25	3	0.15	0.4	3.4
Setaria leucopila	25	3	0.18	0.4	3.4
Physalis sp.	25	3	0.13	0.3	3.3
Polygonum sp.	25	3	0.1	0.2	3.2
Unident. grass	25	3	0.1	0.2	3.2
Eclipta prostrata	25	3	0.05	0.1	3.1
Fraxinus berlandieriana	25	3	0.03	0.1	3.1
Melothria pendula	25	3	0.05	0.1	3.1
			41.41		

Shrub layer. Summary. 40 meters					
Celtis pallida	75	42.9	24.55	77.8	120.7
Opuntia engelmannii	50	28.6	6.2	19.6	48.2
Celtis laevigata	25	14.3	0.68	2.1	16.4
Acacia minuata	25	14.3	0.15	0.5	14.8
			31.58		

Tree layer. Summary. 40 meters					
Prosopis glandulosa	75	37.5	44.75	45.1	82.6
Fraxinus berlandieriana	50	25	19.5	19.6	44.6
Celtis laevigata	25	12.5	21.88	22	34.5
Parkinsonia aculeata	25	12.5	12.5	12.6	25.1
Celtis pallida	25	12.5	0.63	0.6	13.1
			99.26		

Transect 3. 10 meters downstream from Transect 1.

	% cover	Rel. cover
Ground layer		
0-10 meters		
Paspalum lividum	30.2	48.6
Cynodon dactylon	25.6	41.2
Ipomoea amnicola	2	3.2
Commelina erecta	2	3.2

Appendix 2. Salineño

Cyperus sp.	1.4	2.3
Dichanthium aristatum	0.4	0.6
Panicum maximum	0.3	0.5
Paspalum virgatum	0.2	0.3
Unident. grass	0.1	0.2
	62.2	
10-20 meters		
Dichanthium annulatum	11.3	43.8
Chromolaena odorata	3.9	15.1
Clematis drummondii	3.1	12
Setaria leucopila	2.7	10.5
Mirabilis jalapa	2.6	10.1
Physalis sp.	1.7	6.6
Ruellia nudiflora	0.3	1.2
Celtis pallida	0.2	0.8
	25.8	
20-30 meters		
Cenchrus ciliaris	27.3	60
Physalis sp.	4.2	9.2
Clematis drummondii	3.9	8.6
Ruellia nudiflora	2.5	5.5
Abutilon sp.	2	4.4
Celtis pallida	1.9	4.2
Calyptocarpus vialis	1.7	3.7
Setaria leucopila	0.6	1.3
Cocculus diversifolius	0.5	1.1
Mirabilis jalapa	0.5	1.1
Celtis laevigata	0.4	0.9
	45.5	
30-40 meters		
Cenchrus ciliaris	28	97.2
Calyptocarpus vialis	0.5	1.7
Rhynchosida physocalyx	0.3	1
	28.8	
Shrub layer		
0-10 meters		
NO SHRUBS		
10-20 meters		
Celtis pallida	54.3	70.1
Celtis laevigata	19.7	25.4
Diospyros texana	2.5	3.2
Ziziphus obtusifolia	1	1.3
	77.5	
20-30 meters		
Celtis pallida	4.9	73.1
Opuntia engelmannii	1.8	26.9
	6.7	
30-40 meters		
Celtis pallida	28.2	67.3
Opuntia engelmannii	13.7	32.7
	41.9	

Appendix 2. Salineño

Tree layer		
0-10 meters		
Fraxinus berlandieriana	62	
10-20 meters		
Acacia minuata	22	55.7
Celtis laevigata	17.5	44.3
	39.5	
20-30 meters		
Acacia minuata	82.5	72.1
Celtis pallida	32	27.9
	114.5	
30-40 meters		
Prosopis glandulosa	33	

Transect 3. Summary of 40 meters.

	Freq.	Rel. freq.	% Cover	Rel. cover	IV
Ground layer					
Cenchrus ciliaris	50	6.5	13.83	33.9	40.4
Paspalum lividum	25	3.2	7.55	18.5	21.7
Cynodon dactylon	25	3.2	6.4	15.7	18.9
Clematis drummondii	50	6.5	1.75	4.3	10.8
Physalis sp.	50	6.5	1.48	3.6	10.1
Dichanthium annulatum	25	3.2	2.83	6.9	10.1
Setaria leucopila	50	6.5	0.83	2	8.5
Mirabilis jalapa	50	6.5	0.78	1.9	8.4
Ruellia nudiflora	50	6.5	0.7	1.7	8.2
Celtis pallida	50	6.5	0.53	1.3	7.8
Calyptocarpus vialis	50	6.5	0.55	1.3	7.8
Chromolaena odorata	25	3.2	1	2.4	5.6
Ipomoea amnicola	25	3.2	0.5	1.2	4.4
Commelina erecta	25	3.2	0.5	1.2	4.4
Abutilon sp.	25	3.2	0.5	1.2	4.4
Cyperus sp.	25	3.2	0.35	0.9	4.1
Unident. grass	25	3.2	0.23	0.6	3.8
Cocculus diversifolius	25	3.2	0.13	0.3	3.5
Dichanthium aristatum	25	3.2	0.1	0.2	3.4
Panicum maximum	25	3.2	0.08	0.2	3.4
Celtis laevigata	25	3.2	0.1	0.2	3.4
Rhynchosida physocalyx	25	3.2	0.08	0.2	3.4
Paspalum virgatum	25	3.2	0.05	0.1	3.3
			40.85		
Shrub layer					
Celtis pallida	75	37.5	21.85	69.3	106.8
Celtis laevigata	25	12.5	4.93	15.6	28.1
Opuntia engelmannii	50	25	3.88	12.3	37.3
Diospyros texana	25	12.5	0.63	2	14.5
Ziziphus obtusifolia	25	12.5	0.25	0.8	13.3
			31.54		
Tree layer					
Acacia minuata	50	33.3	26.13	42	75.3

Fraxinus berlandieriana	25	16.7	15.5	24.9	41.6
Prosopis glandulosa	25	16.7	8.25	13.3	30
Celtis pallida	25	16.7	8	12.9	29.6
Celtis laevigata	25	16.7	4.38	7	23.7
			62.26		

Summary of 3 x 40 meter transects. Pooled data.

	Freq.	Rel. freq.	% Cover	Rel. cover	IV
Ground layer					
Cenchrus ciliaris	33.3	3.8	10.78	25	28.8
Paspalum lividum	25	2.9	8.28	19.2	22.1
Mirabilis jalapa	66.7	7.6	3.57	8.3	15.9
Clematis drummondii	50	5.7	3.97	9.2	14.9
Cynodon dactylon	33.3	3.8	3.5	8.1	11.9
Ruellia nudiflora	66.7	7.6	1.64	3.8	11.4
Paspalum virgatum	41.7	4.8	1.61	3.7	8.5
Celtis pallida	50	5.7	1.01	2.3	8
Physalis sp.	41.7	4.8	0.81	1.9	6.7
Setaria leucopila	41.7	4.8	0.64	1.5	6.3
Dichanthium annulatum	16.7	1.9	1.81	4.2	6.1
Ipomoea amnicola	33.3	3.8	0.78	1.8	5.6
Calyptocarpus vialis	33.3	3.8	0.58	1.3	5.1
Cocculus diversifolius	33.3	3.8	0.4	0.9	4.7
Malvastrum coromandelianum	33.3	3.8	0.28	0.7	4.5
Cyperus sp.	25	2.9	0.33	0.8	3.7
Commelina erecta	25	2.9	0.28	0.7	3.6
Celtis laevigata	25	2.9	0.27	0.6	3.5
Dichanthium aristatum	25	2.9	0.22	0.5	3.4
Rhynchosida physocalyx	16.7	1.9	0.16	0.4	2.3
Eriochloa punctata	8.3	1	0.55	1.3	2.3
Solanum triquetrum	16.7	1.9	0.14	0.3	2.2
Unident. grass	16.7	1.9	0.11	0.3	2.2
Chromolaena odorata	8.3	1	0.33	0.8	1.8
Abutilon sp.	8.3	1	0.17	0.4	1.4
Cyphomeris crassifolia	8.3	1	0.19	0.4	1.5
Symphyotrichum subulatum	8.3	1	0.16	0.4	1.4
Unident. dicot	8.3	1	0.19	0.4	1.4
Ciclospermum leptophyllum	8.3	1	0.03	0.1	1.1
Unident. dicot seedling	8.3	1	0.06	0.1	1.1
Prosopis glandulosa	8.3	1	0.05	0.1	1.1
Polygonum sp.	8.3	1	0.03	0.1	1.1
Acacia minuata	8.3	1	0.05	0.1	1.1
Panicum maximum	8.3	1	0.03	0.1	1.1
Eclipta prostrata	8.3	1	0.02	<0.1	1
Fraxinus berlandieriana	8.3	1	0.01	<0.1	1
Melothria pendula	8.3	1	0.01	<0.1	1
			43.06		
Shrub layer					
Celtis pallida	75	39.1	28.06	67.1	106.2
Opuntia engelmannii	50	26.1	8.18	19.6	45.7
Celtis laevigata	33.3	17.4	5.2	12.4	29.8

Appendix 2. Salineño

Diospyros texana	8.3	4.3	0.21	0.5	4.8
Ziziphus obtusifolia	8.3	4.3	0.08	0.2	4.5
Acacia minuata	8.3	4.3	0.05	0.1	4.4
Cocculus diversifolius	8.3	4.3	0.05	0.1	4.4
			41.83		
Tree layer					
Prosopis glandulosa	50	27.3	28.5	34.4	61.7
Fraxinus berlandieriana	41.7	22.7	21	25.4	48.1
Celtis laevigata	33.3	18.2	12.33	14.9	33.1
Acacia minuata	25	13.6	9.71	11.7	25.3
Celtis pallida	25	13.6	3.96	4.8	18.4
Parkinsonia aculeata	8.3	4.5	7.29	8.8	13.3
			82.79		

29 May 2000. Santa Ana National Wildlife Refuge. Jagaurundi trail head. Transect 1 is upstream close to transect 1 (July 1997 reading). The site matches with imagery obtained from USDA-Weslaco in 1997. Transect begins in mud; about 50 cm above the water's edge.

Transect 1.

Ground layer

0-10 meters	% cover	Rel. cover
Panicum maximum	6.3	52.9
Ampelopsis arborea	3.2	26.9
Setaria leucopila	1.4	11.8
Clematis drummondii	1.0	8.4
	11.9	

10-20 meters		
Setaria leucopila	13.0	29.5
Wissadula amplissima	12.1	27.5
Celtis laevigata	4.4	10.0
Panicum maximum	4.1	9.3
Tragia glanduligera	3.3	7.5
Celtis pallida	2.6	5.9
Cocculus diversifolius	1.2	2.7
Rivina humilis	0.7	1.6
Justicia pilosella	0.7	1.6
Leucaena pulverulenta	0.6	1.4
Ehretia anacua	0.5	1.1
Malvastrum coromandel.	0.5	1.1
Serjania brachycarpa	0.3	0.7
	44.0	

(Celtis laevigata, C. pallida, Leucaena pulverulenta, Ehretia anacua are seedlings).
Malvastrum coromandelianum

20-30 meters		
Setaria leucopila	12.1	25.7
Justicia pilosella	7.4	15.7
Opuntia leptocaulis	6.2	13.2
Panicum maximum	4.9	10.4
Salvia coccinea	4.5	9.6
Wissadula amplissima	4.5	9.6
Celtis pallida	2.7	5.7
Malvastrum coromand.	1.9	4.0
Mimosa malacophylla	1.5	3.2
Rivina humilis	0.8	1.7
Cocculus diversifolius	0.4	0.8
Serjania brachycarpa	0.2	0.4
	47.1	

Transect 1. **Ground layer. Summary**

	Freq.	Rel. freq.	% cover	Rel. cover	IV
Setaria leucopila	100.0	10.3	8.83	25.7	36.0
Panicum maximum	100.0	10.3	5.10	14.9	25.2
Wissadula amplissima	66.7	6.9	5.53	16.1	23.0
Justicia pilosella	66.7	6.9	2.70	7.9	14.8
Celtis pallida	66.7	6.9	1.77	5.1	12.0
Opuntia leptocaulis	33.3	3.4	2.07	6.0	9.4
Malvastrum coromand.	66.7	6.9	0.80	2.3	9.2
Cocculus diversifolius	66.7	6.9	0.53	1.6	8.5
Rivina humilis	66.7	6.9	0.50	1.5	8.4
Salvia coccinea	33.3	3.4	1.50	4.4	7.8
Celtis laevigata	33.3	3.4	1.47	4.3	7.7
Serjania brachycarpa	66.7	6.9	0.17	0.5	7.4
Tragia glanduligera	33.3	3.4	1.10	3.2	6.6
Ampelopsis arborea	33.3	3.4	1.07	3.1	6.5
Mimosa malacophylla	33.3	3.4	0.50	1.5	4.9
Clematis drummondii	33.3	3.4	0.33	1.0	4.4
Leucaena pulverulenta	33.3	3.4	0.20	0.6	4.0
Ehretia anacua	33.3	3.4	0.17	0.5	3.9
			34.34		

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Transect 1. Cover values. **Shrub layer**. % cover and relative cover.

0-10 meters		
Phragmites australis	78.0	79.6
Celtis laevigata	15.0	15.3
Ulmus crassifolia	5.0	5.1
	98.0	
10-20 meters		
Celtis laevigata	3.4	
20-30 meters		
Zanthoxylum fagara	14.5	65.3
Opuntia leptocaulis	4.7	21.2
Celtis pallida	3.0	13.5
	22.2	

Transect 1. Cover values. **Shrubs; summary**. Frequency, relative frequency, % cover, relative cover, and importance value

Phragmites australis	33.3	14.3	26.00	63.1	77.4
Celtis laevigata	66.7	28.6	6.13	14.9	43.5
Zanthoxylum fagara	33.3	14.3	4.83	11.7	26.0

Ulmus crassifolia	33.3	14.3	1.67	4.0	18.3
Opuntia leptocaulis	33.3	14.3	1.57	3.8	18.1
Celtis pallida	33.3	14.3	1.00	2.4	16.7
			41.20		

Transect 1. Cover values. **Trees.** % cover and relative cover

0-10 meters		
Fraxinus berlandieriana	75.0	47.8
Leucaena pulverulenta	45.0	28.7
Salix exigua	37.0	23.6
	157.0	

10-20 meters		
Leucaena pulverulenta	24.0	32.0
Celtis laevigata	23.1	30.8
Fraxinus berlandieriana	15.0	20.0
Ulmus crassifolia	13.0	17.3
	75.1	

20-30 meters		
Celtis pallida	52.0	69.3
Celtis laevigata	17.0	22.7
Ehretia anacua	6.0	8.0
	75.0	

Transect 1. **Trees. Summary**. Frequency, relative frequency, % cover, relative cover, and importance values.

Fraxinus berlandieriana	66.7	20.0	30.00	29.3	49.3
Leucaena pulverulenta	66.7	20.0	23.00	22.5	42.5
Celtis laevigata	66.7	20.0	13.37	13.1	33.1
Celtis pallida	33.3	10.0	17.33	16.9	26.9
Salix exigua	33.3	10.0	12.33	12.0	22.0
Ulmus crassifolia	33.3	10.0	4.33	4.2	14.2
Ehretia anacua	33.3	10.0	2.00	2.0	12.0
			102.36		

Transect 1. **Shrub density, heights, and dbh** (diameter at breast height).

0-10 meters	height	dbh (cm)
Phragmites australis (large colony)	ca. 2.5 m	
Ulmus crassifolia (1)	2.25	4.1
Celtis laevigata (1)	2.40	7.3

10-20 meters		
Celtis laevigata (1)	2.0 m	2.2
20-30 meters		
Opuntia leptocaulis (1)	1.2 m	3.3 (3 stems)
Celtis pallida (1)	2.7 m	2.3, 1.6, 2.4
Zanthoxylum fagara (1)	2.35	1.8, 1.7

Transect 1. **Tree density, heights (m), and dbh (cm).**

0-10 meters		
Salix exigua (2)	3.5 m, 3.6 m	16.6, 3.5
Fraxinus berlandieriana (3)	3.1, 8.0, 5.5	5.3, 15.4, 7.2
Leucaena pulverulenta (1)	6.5	16.0
10-20 meters		
Fraxinus berlandieriana (1)	7.4	7.3
Ulmus crassifolia (1)	7.3	12.4
Celtis laevigata (1)	4.4	4.2
Leucaena pulverulenta (1)	6.0	9.1
20-30 meters		
Celtis laevigata (1)	6.0	15.0
Celtis pallida (2)	3.9, 3.1	3.6, 2.4, 1.6, 4.4, 2.0, 1.8
Ehretia anacua (1)	4.2	7.5

Transect 2. 26 May 2000. Transect 2 is located downstream from the Jagaurundi trailhead. This transect corresponds to transect 2 (July 1997). River bank is too steep to start at the water's edge. We started 1.0 m above the water line. We are about 1.0 m downstream from a beaver's burrow. Small plateau at 50 cm; a sharp incline at 150 cm

Ground layer. % cover and relative cover

0-10 meters		
Ampelopsis arborea	39.7	81.5
Panicum maximum	8.5	17.5
Leucaena pulverulenta	0.5	1.0
	48.7	
10-20 meters		
Sideroxylon celastrina	14.6	42.1
Panicum maximum	6.3	18.2
Rivina humilis	4.9	14.1
Ehretia anacua	2.3	6.6
Chloroleucon ebano	2.1	6.1
Ampelopsis arborea	2.0	5.8

Forestiera angustifolia	1.0	2.9
Cocculus diversifolius	0.7	2.0
Mimosa malacophylla	0.5	1.4
Leucaena pulverulenta	0.2	0.6
Condalia hookeri	0.1	0.3
	34.7	

(Sideroxylon, Ehretia, Chloroleucon, Forestieria, Leucaena, and Condalia are seedlings).

20-30 meters

Rivina humilis	5.2	26.1
Mimosa malacophylla	4.4	22.1
Sideroxylon celastrina	2.3	11.6
Amyris texana	2.0	10.1
Setaria leucopila	2.0	10.1
Chloroleucon ebano	1.8	9.0
Salvia coccinea	0.6	3.0
Cocculus diversifolius	0.5	2.5
Serjania brachycarpa	0.5	2.5
Ehretia anacua	0.4	2.0
Justicia pilosella	0.2	1.0
	19.9	

Transect 2. **Ground layer. Summary**. Frequency, relative frequency, % cover, relative cover, and importance value

Ampelopsis arborea	66.7	8.0	13.90	40.4	48.4
Sideroxylon celastrina	66.7	8.0	5.63	16.4	24.4
Panicum maximum	66.7	8.0	4.93	14.3	22.3
Rivina humilis	66.7	8.0	3.37	9.8	17.8
Mimosa malacophylla	66.7	8.0	1.63	4.7	12.7
Chloroleucon ebano	66.7	8.0	1.30	3.8	11.8
Ehretia anacua	66.7	8.0	0.90	2.6	10.6
Cocculus diversifolius	66.7	8.0	0.40	1.2	9.2
Leucaena pulverulenta	66.7	8.0	0.23	0.7	8.7
Setaria leucopila	33.3	4.0	0.67	1.9	5.9
Amyris texana	33.3	4.0	0.67	1.9	5.9
Forestiera angustifolia	33.3	4.0	0.33	1.0	5.0
Salvia coccinea	33.3	4.0	0.20	0.6	4.6
Serjania brachycarpa	33.3	4.0	0.17	0.5	4.5
Justicia pilosella	33.3	4.0	0.07	0.2	4.2
Condalia hookeri	33.3	4.0	0.03	0.1	4.1
			34.43		

Transect 2. **Shrubs.** Cover values. % cover and relative cover

0-10 meters		
Phragmites australis	2.0	
10-20 meters		
Ehretia anacua	4.7	
20-30 meters		
Amyris texana	12.0	69.8
Chloroleucon ebano	5.2	30.2
	17.2	

Transect 2. **Shrub cover values. Summary**. Frequency, relative frequency, % cover, relative cover, and importance value

Amyris texana	33.3	25.0	4.00	50.2	75.2
Chloroleucon ebano	33.3	25.0	1.73	21.8	46.8
Ehretia anacua	33.3	25.0	1.57	19.7	44.7
Phragmites australis	33.3	25.0	0.67	8.4	33.4
			7.97		

Transect 2. **Tree layer**. Cover values. % cover and relative cover.

0-10 meters		
Salix exigua	9.0	59.2
Fraxinus berlandieriana	6.2	40.8
	15.2	
10-20 meters		
Ulmus crassifolia	43.0	26.5
Condalia hookeri	33.0	20.4
Diospyros texana	25.0	15.4
Ziziphus obtusifolia	24.0	14.8
Leucaena pulverulenta	20.0	12.3
Ehretia anacua	17.0	10.5
	162.0	
20-30 meters		
Sideroxylon celastrina	100.0	77.5
Ziziphus obtusifolia	16.0	12.4
Chloroleucon ebano	7.0	5.4
Zanthoxylum fagara	6.0	4.7
	129.0	

Transect 2. **Tree cover values. Summary**. Frequency, relative frequency, % cover, relative cover, and importance value.

Sideroxylon celastrina	33.3	8.3	33.33	32.7	41.0
Ziziphus obtusifolia	66.7	16.7	13.33	13.1	29.8
Ulmus crassifolia	33.3	8.3	14.33	14.0	22.3
Condalia hookeri	33.3	8.3	11.00	10.8	19.1
Diospyros texana	33.3	8.3	8.33	8.2	16.5
Leucaena pulverulenta	33.3	8.3	6.67	6.5	14.8
Ehretia anacua	33.3	8.3	5.67	5.6	13.9
Salix exigua	33.3	8.3	3.00	2.9	11.2
Chloroleucon ebano	33.3	8.3	2.33	2.3	10.6
Fraxinus berlandieriana	33.3	8.3	2.07	2.0	10.3
Zanthoxylum fagara	33.3	8.3	2.00	2.0	10.3
			102.06		

Transect 2. **Shrub density, height (m), and dbh (cm)**

0-10 meters
Phragmites australis (colony)

10-20 meters	height	diameter
Ehretia anacua (1)	1.6	2.8
20-30 meters		
Amyris texana (1)	1.3	0.7 cm x 8 stems
Chloroleucon ebano (1)	1.35	0.3, 0.2

Transect 2. **Tree density, height (m), and dbh (cm).**

0-10 meters		
Salix exigua (1)	3.5	22.7
Fraxinus berlandieriana (1)	(not recorded)	
10-20 meters		
Leucaena pulverulenta (1)	18.0	21.5
Ulmus crassifolia (1)	10.5	24.9
Condalia hookeri (1)	5.0	11.3, 12.4
Ehretia anacua (1)	5.7	21.9
Diospyros texana (1)	7.0	12.2, 14.1
Ziziphus obtusifolia (1)	3.9	5.0, 10.1

Transect 3. 26 May 2000. Transect 3 is downstream from transect 2. This transect corresponds to transect 3 of July 1997.

Ground layer. % cover and relative cover

0-10 meters		
Panicum maximum	42.6	88.4
Mikania scandens	3.2	6.6
Leucaena pulverulenta	2.4	5.0
	48.2	

10-20 meters		
Panicum maximum	17.0	68.0
Ulmus crassifolia	3.9	15.6
Fraxinus berlanderiana	0.9	3.6
Chloroleucon ebano	0.6	2.4
Leucaena pulverulenta	0.5	2.0
Cocculus diversifolius	0.5	2.0
Tragia glanduligera	0.4	1.6
Zanthoxylum fagara	0.2	0.8
Serjania brachycarpa	0.1	0.4
	25.0	

20-30 meters		
Croton cortesianus	2.4	28.6
Tamaulipa azurea	2.2	26.2
Amyris texana	1.7	20.2
Malpighia glabra	1.0	11.9
Mimosa malacophylla	0.6	7.1
Justicia pilosella	0.3	3.6
Rivina humilis	0.2	2.4
	8.4	

Transect 3. **Ground layer summary**. Frequency, relative frequency, % cover, relative cover, and importance value.

Panicum maximum	66.7	10.5	19.87	73.9	84.4
Leucaena pulverulenta	66.7	10.5	0.97	3.6	14.2
Ulmus crassifolia	33.3	5.3	1.30	4.8	10.1
Mikania scandens	33.3	5.3	1.07	4.0	9.3
Croton cortesianus	33.3	5.3	0.80	3.0	8.3
Tamaulipa azurea	33.3	5.3	0.73	2.7	8.0
Amyris texana	33.3	5.3	0.57	2.1	7.4
Malpighia glabra	33.3	5.3	0.33	1.2	6.5
Fraxinus berlandieriana	33.3	5.3	0.30	1.1	6.4
Chloroleucon ebano	33.3	5.3	0.20	0.7	6.0

Mimosa malacophylla	33.3	5.3	0.20	0.7	6.0
Cocculus diversifolius	33.3	5.3	0.17	0.6	5.9
Tragia glanduligera	33.3	5.3	0.13	0.5	5.8
Justicia pilosella	33.3	5.3	0.10	0.4	5.7
Rivina humilis	33.3	5.3	0.07	0.2	5.5
Zanthoxylum fagara	33.3	5.3	0.07	0.2	5.5
Serjania brachycarpa	33.3	5.3	0.03	0.1	5.4
			26.91		

Transect 3. **Shrubs.** % cover and relative cover.

0-10 meters

Leucaena pulverulenta	1.5

10-20 meters

Amyris texana	6.1	64.9
Phaulothamnus spinescens	3.3	35.1
	9.4	

20-30 meters

Phaulothamnus spines.	25.8	47.9
Ehretia anacua	8.0	14.8
Celtis pallida	8.0	14.8
Sideroxylon celastrina	7.1	13.2
Amyris texana	4.5	8.3
Ziziphus obtusifolia	0.5	0.9
	53.9	

Shrubs.
Transect 3.mmary; frequency, relative frequency, % cover, relative cover, and importance value.

Phaulothamnus spines.	66.7	22.2	9.70	44.9	67.1
Amyris texana	66.7	22.2	3.53	16.4	38.6
Celtis pallida	33.3	11.1	2.67	12.3	23.4
Ehretia anacua	33.3	11.1	2.67	12.3	23.4
Sideroxylon celastrina	33.3	11.1	2.37	11.0	22.1
Leucaena pulverulenta	33.3	11.1	0.50	2.3	13.4
Ziziphus obtusifolia	33.3	11.1	0.17	0.8	11.9
			21.61		

Transect 3. **Tree cover values**. % cover and relative cover

0-10 meters		
Celtis laevigata	85.0	61.2
Fraxinus berlandieriana	30.0	21.6
Leucaena pulverulenta	14.0	10.1
Salix exigua	10.0	7.2
	139.0	
10-20 meters		
Chloroleucon ebano	74.0	30.9
Ehretia anacua	55.0	23.0
Fraxinus berlanderiana	37.5	15.7
Celtis laevigata	37.0	15.4
Condalia hookeri	35.0	14.6
Celtis pallida	1.1	0.5
	239.6	
20-30 meters		
Sideroxylon celastrina	49.5	37.8
Chloroleucon ebano	41.0	31.3
Ehretia anacua	25.0	19.2
Celtis pallida	15.5	11.8
	131.0	

Woody vines

Cocculus diversifolius	0.5

Transect 3. **Trees summary**. Frequency, relative frequency, % cover, relative cover, and importance value.

Celtis laevigata	66.7	14.3	40.67	23.9	38.2
Chloroleucon ebano	66.7	14.3	38.33	22.6	36.9
Ehretia anacua	66.7	14.3	26.67	15.7	30.0
Fraxinus berlandieriana	66.7	14.3	22.50	13.2	27.5
Celtis pallida	66.7	14.3	5.53	3.3	17.6
Sideroxylon celastrina	33.3	7.1	16.50	9.7	16.8
Condalia hookeri	33.3	7.1	11.67	6.9	14.0
Leucaena pulverulenta	33.3	7.1	4.67	2.7	9.8
Salix exigua	33.3	7.1	3.33	2.0	9.1
			169.87		

Transect 3. **Shrubs. Density, height (m), dbh (cm)**

0-10 meters	height	dbh (cm)
Leucaena pulverulenta (1)	2.25	0.6
10-20 meters		
Amyris texana (2)	1.6, 1.05	0.4, 1.0 x 5 stems
Phaulothamnus spinescens (2)	1.05, 2.55	1.1, 1.9, 2.0, 1.7, 1.2, 1.0
20-30 meters		
Phaulothamnus spinescens (2)	2.85, 1.5	1.7 x 3 stems; 0.3. 0.2, 0.8
Amyris texana (1)	1.5	0.9 x 5 stems
Celtis pallida (1)	2.95	2.0, 1.1
Ziziphus obtusifolia (1)	1.6	1.3, 0.6, 1.0
Sideroxylon celastrina (1)	(not recorded)	0.8
Ehretia anacua (1)	(not recorded)	1.4

Transect 3. **Trees. Density, height (m), and dbh (cm).**

0-10 meters		
Salix exigua (1)	4.5	7.0
Celtis laevigata (4)	4.6, 5.1, 6.0, 4.5	4.5, 5.5, 12.2, 3.6
Leucaena pulverulenta (1)	3.5	0.7, 1.5
Fraxinus berlanderiana (1)	8.0	12.3
10-20 meters		
Fraxinus berlandieriana (previous interval)		
Celtis laevigata (1)	6.3	8.3
Ehretia anacua (2)	3.2, 4.1	4.3, 12.9
Chloroleucon ebano (2)	6.9, 8.1	16.7, 8.5, 24.5
Condalia hookeri (1)	5.3	12.9, 6.0
Celtis pallida (1)	3.2	4.7
20-30 meters		
Sideroxylon celastrina (2)	5.6, 3.6	11.2, 8.2
Ehretia anacua (1)	4.5	7.3
Chloroleucon ebano (2)	7.0, 7.0	9.3, 14.9
Celtis pallida (2)	4.8, 3.0	5.2, 3.2

Santa Ana National Wildlife Refuge. Summary of three transects. 30 meters x 3.
Ground layer. Frequency, relative frequency, % cover, relative cover, and importance value.

Panicum maximum	77.8	9.9	9.97	31.3	41.2
Ampelopsis arborea	33.3	4.2	4.99	15.6	19.8
Setaria leucopila	44.4	5.6	3.17	9.9	15.5
Rivina humilis	55.6	7.0	1.31	4.1	11.1
Wissadula amplissima	22.2	2.8	1.84	5.8	8.6
Justicia pilosella	44.4	5.6	0.96	3.0	8.6
Leucaena pulverulenta	55.6	7.0	0.47	1.5	8.5
Cocculus diversifolius	55.6	7.0	0.37	1.1	8.1
Mimosa malacophylla	44.4	5.6	0.78	2.4	8.0
Sideroxylon celastrina	11.1	1.4	1.88	5.9	7.3
Serjania brachycarpa	44.4	5.6	0.12	0.4	6.0
Chloroleucon ebano	33.3	4.2	0.50	1.6	5.8
Ehretia anacua	33.3	4.2	0.36	1.1	5.3
Salvia coccinea	22.2	2.8	0.57	1.8	4.6
Tragia glanduligera	22.2	2.8	0.41	1.3	4.1
Opuntia leptocaulis	11.1	1.4	0.69	2.2	3.6
Celtis pallida	11.1	1.4	0.59	1.8	3.2
Celtis laevigata	11.1	1.4	0.49	1.5	2.9
Ulmus crassifolia	11.1	1.4	0.43	1.4	2.8
Mikania scandens	11.1	1.4	0.36	1.1	2.5
Croton cortesianus	11.1	1.4	0.27	0.8	2.2
Tamaulipa azurea	11.1	1.4	0.24	0.8	2.2
Clematis drummondii	11.1	1.4	0.11	0.3	1.7
Forestiera angustifolia	11.1	1.4	0.11	0.3	1.7
Malpighia glabra	11.1	1.4	0.11	0.3	1.7
Fraxinus berlandieriana	11.1	1.4	0.10	0.3	1.7
Zanthoxylum fagara	11.1	1.4	0.02	0.1	1.5
Condalia hookeri	11.1	1.4	0.01	<0.1	1.4
			31.91		

Shrubs. Summary of three transects. Frequency, relative frequency, % cover, relative cover, and importance value.

Phragmites australis	22.2	10.0	8.89	37.7	47.7
Amyris texana	33.3	15.0	2.51	10.6	25.6
Phaulothamnus spinesc.	22.2	10.0	3.23	13.7	23.7
Celtis laevigata	22.2	10.0	2.04	8.7	18.7
Ehretia anacua	22.2	10.0	1.41	6.0	16.0
Zanthoxylum fagara	11.1	5.0	1.61	6.8	11.8
Sideroxylon celastrina	11.1	5.0	0.79	3.3	8.3
Ulmus crassifolia	11.1	5.0	0.56	2.4	7.4
Chloroleucon ebano	11.1	5.0	0.58	2.4	7.4
Opuntia leptocaulis	11.1	5.0	0.52	2.2	7.2

Leucaena pulverulenta	11.1	5.0	0.17	0.8	5.8
Ziziphus obtusifolia	11.1	5.0	0.06	0.2	5.8
			23.59		

Trees. Summary of three transects. Frequency, relative frequency, % cover, relative cover, and importance value.

Fraxinus berlandieriana	55.6	13.9	18.19	14.6	28.5
Celtis laevigata	44.4	11.1	18.01	14.4	25.5
Leucaena pulverulenta	44.4	11.1	11.44	9.2	20.3
Ehretia anacua	44.4	11.1	11.44	9.2	20.3
Chloroleucon ebano	33.3	8.3	13.56	10.9	19.2
Sideroxylon celastrina	22.2	5.6	16.61	13.3	18.9
Celtis pallida	33.3	8.3	7.62	6.1	14.4
Salix exigua	33.3	8.3	6.22	5.0	13.3
Condalia hookeri	22.2	5.6	7.56	6.1	11.7
Ulmus crassifolia	22.2	5.6	6.22	5.0	10.6
Ziziphus obtusifolia	22.2	5.6	4.44	3.6	9.2
Diospyros texana	11.1	2.8	2.78	2.2	5.0
Zanthoxylum fagara	11.1	2.8	0.67	0.5	3.3
			124.76		

Appendix 3. New riparian survey sites

Table 1 - Comparison of the relative importance of species in the tree and shrub layers at **Santa Maria**, Cameron County, Texas. Freq. = Frequency, Rel.freq. = Relative Frequency, Rel. cov. = Relative Cover, Imp. Val. = Importance Value (the sum of relative frequency and relative cover).

Layer	Species	Freq.	Rel. freq.	% Cover	Rel. cov.	Imp. Val.
Tree	*Celtis laevigata*	66.7	34.8	56.5	63.8	98.6
	Arundo donax	41.7	21.7	10.7	12.1	33.8
	Salix exigua	25.0	13.0	5.5	6.2	19.2
	Ehretia anacua	16.7	8.7	5.1	5.8	14.5
	Acacia minuata	8.3	4.3	6.3	7.2	11.5
	Phragmites australis	16.7	8.7	0.8	0.9	9.6
	Celtis pallida	8.3	4.3	2.0	2.3	6.6
	Ziziphus obtusifolia	8.3	4.3	1.5	1.7	6.0
	Total			88.4		
Shrub	*Celtis laevigata*	33.3	50.0	3.1	63.5	113.5
	Salix exigua	8.3	12.5	0.9	18.9	31.4
	Baccharis salicifolia	8.3	12.5	0.5	10.3	22.8
	Lantana camara	8.3	12.5	0.2	3.9	16.4
	Phragmites australis	8.3	12.5	0.2	3.9	16.4
	Total			4.9		

Table 2 - Comparison of the relative importance of species occurring in the ground layer at **Santa Maria**, Cameron County, Texas. Freq. = frequency, Rel. freq. = Relative Frequency, Rel. cov. = Relative Cover, Imp. Val. = Importance Value (the sum of relative frequency and relative cover).

Species	Freq.	Rel. freq.	% Cover	Rel. cov.	Imp. Val.
Panicum maximum	91.7	15.7	32.07	48.7	64.4
Clematis drummondii	91.7	15.7	12.46	18.8	34.5
Rivina humilus	25.0	4.3	9.36	14.1	18.4
Ampelopsis arborea	50.0	8.6	4.49	6.8	15.4
Rubus riograndis	50.0	8.6	0.35	0.5	9.1
Capsicum annuum	33.3	5.7	1.63	2.5	8.2
Eichhornia crassipes	25.0	4.3	1.82	2.7	7.0
Chromolaena odorata	25.0	4.3	1.25	1.9	6.2
Ziziphus obtusifolia	25.0	4.3	0.23	0.3	4.6
Mikania scandens	16.7	2.9	0.87	1.3	4.2
Celtis pallida	16.7	2.9	0.24	0.4	3.3
Cissus incisa	16.7	2.9	0.18	0.3	3.2
Sarcostemma sp.	16.7	2.9	0.07	0.1	3.0
Unident. Dicot seedling	16.7	2.9	0.06	0.1	3.0
Lantana camera	8.3	1.4	0.71	1.1	2.5
Celtis laevigata	8.3	1.4	0.26	0.4	1.8
Phragmites australis	8.3	1.4	0.10	0.2	1.6
Eriochloa punctata	8.3	1.4	0.08	0.1	1.5
Polygonum sp.	8.3	1.4	0.05	0.1	1.5
Setaria leucopila	8.3	1.4	0.05	0.1	1.5
Arundo donax	8.3	1.4	0.06	0.1	1.5
Solanum triquetrum	8.3	1.4	0.03	0.1	1.5
Cocculus diversifolius	8.3	1.4	0.03	0.1	1.5
Poaceae seedling	8.3	1.4	0.01	0.0	1.4
Total cover			66.46		

Table 3 - Comparison of the relative importance of species occurring in the tree and shrub layers at **La Joya**, Hidalgo County, Texas. Freq. = Frequency, Rel. freq. = Relative Frequency, Rel. cov. = Relative Cover, Imp. Val. = Importance Value (the sum of relative frequency and relative cover).

Layer	Species	Freq.	Rel. Freq.	% Cover	Rel. Cover	Imp. Val.
Tree	*Celtis laevigata*	66.7	39.4	33.86	47.1	86.5
	Acacia minuata	35.7	21.1	21.13	29.4	50.5
	Celtis pallida	16.7	9.9	4.07	5.7	15.6
	Salix exigua	14.3	8.5	5.00	6.9	15.4
	Fraxinus berlandieriana	9.5	5.6	1.91	2.6	8.2
	Ulmus crassifolia	7.1	4.2	2.02	2.8	7.0
	Tamarix aphylla	4.8	2.8	1.93	2.7	5.5
	Baccharis neglecta	4.8	2.8	0.83	1.2	4.0
	Ehretia anacua	4.8	2.8	0.61	0.8	3.6

	Salix nigra	4.8	2.8	0.60	0.8	3.6
	Total			71.96		
Shrub	*Celtis pallida*	28.6	15.0	1.64	9.8	24.8
	Fraxinus berlandieriana	26.2	13.7	1.85	11.1	24.8
	Salix exigua	14.3	7.5	2.59	15.6	23.1
	Amelopsis arborea	16.7	8.8	2.34	14.1	22.9
	Arundo donax	11.9	6.2	2.43	14.6	20.8
	Celtis laevigata	26.2	13.7	1.13	6.8	20.5
	Cocculus diversifolius	16.7	8.8	0.58	3.5	12.3
	Phragmites australis	2.4	1.3	1.48	8.9	10.2
	Clematis drummondii	11.9	6.2	0.55	3.3	9.5
	Cissus incisa	11.9	6.2	0.26	1.6	7.8
	Leucosyris spinosa	4.8	2.5	0.69	4.1	6.6
	Baccharis neglecta	2.4	1.3	0.62	3.7	5.0
	Ehretia anacua	7.1	3.7	0.15	0.9	4.6
	Ulmus crassifolia	4.8	2.5	0.31	1.9	4.4
	Ziziphus obtusifolia	2.4	1.3	0.03	0.2	1.5
	Tamarix aphylla	2.4	1.3	0.01	0.1	1.4
	Total			16.66		

Table 4 - Comparison of the relative importance of species occurring in the ground layer at **La Joya**, Hidalgo County, Texas. Freq.= Frequency, Rel. freq. = Relative Frequency, Rel. cov. = Relative Cover, Imp. Val. = Importance Value (the sum of relative frequency and relative cover).

Species	Freq.	Rel. freq.	% Cover	Rel. cov.	Imp. Val.
Clematis drummondii	78.6	17.35	6.84	20.55	37.90
Setaria leucopila	52.4	11.57	4.74	14.24	25.81
Panicum maximum	35.7	7.88	4.86	14.60	22.48
Pennisetum ciliare	19.0	4.19	5.69	17.09	21.28
Rivina humilus	40.5	8.94	1.53	4.60	13.54
Cocculus diversifolius	31.0	6.84	1.45	4.36	11.20
Amelopsis arborea	23.8	5.25	1.54	4.63	9.88
Cissus incisa	28.6	6.31	0.55	1.65	7.96
Celtis laevigata	26.2	5.78	0.30	0.90	6.68
Cynodon dactylon	4.8	1.06	1.33	4.00	5.06
Chromolaena odorata	14.3	3.16	0.44	1.32	4.48
Celtis pallida	11.9	2.63	0.41	1.23	3.86
Matela parviflora	14.3	3.16	0.19	0.57	3.73
Dicanthium aristatum	9.5	2.10	0.08	0.24	2.34
Heimia salicifolia	2.4	0.53	0.58	1.74	2.27
Paspalum lividum	2.4	0.53	0.52	1.56	2.09
Eriochloa punctata	2.4	0.53	0.50	1.50	2.03
Leptochloa nealleyi	4.8	1.06	0.17	0.51	1.57
Ulmus crassifolia	4.8	1.06	0.15	0.45	1.51
Fraxinus berlandieriana	4.8	1.06	0.05	0.15	1.21
Ehretia anacua	4.8	1.06	0.05	0.15	1.21
Sarcostemma cynanchoides	4.8	1.06	0.04	0.12	1.18
Teucrium cubense	4.8	1.06	0.03	0.09	1.15
Chloris cucullata	2.4	0.53	0.17	0.51	1.04
Bothriochloa laguroides	2.4	0.53	0.15	0.45	0.98
Vigna luteola	2.4	0.53	0.13	0.39	0.92
Eriocola punctata	2.4	0.53	0.10	0.30	0.83
Salix exigua	2.4	0.53	0.06	0.18	0.71
Ruellia nudiflora	2.4	0.53	0.04	0.12	0.62

Table 4 - continued.

Species	Freq.	Rel. freq.	% Cover	Rel. cov.	Imp. Val.
Acacia minuata	2.4	0.53	0.03	0.09	0.62
Leucosyris spinosa	2.4	0.53	0.03	0.09	0.62
Solanum triquetrum	2.4	0.53	0.01	0.03	0.56
Melothria pendula	2.4	0.53	0.01	0.03	0.56
Arundo donax	2.4	0.53	<0.01	0.00	0.53
Total			33.29		

Table 5 - Comparison of the relative importance of species occurring in the tree and shrub layers at **Escobares**, Starr County, Texas. Freq. = Frequency, Rel. freq. = Relative Frequency, Rel. cov. = Relative Cover, Imp. Val. = Importance Value (the sum of relative frequency and relative cover).

Appendix 3. New riparian survey sites

Layer	Species	Freq.	Rel. freq.	% Cover	Rel. cov.	Imp. Val.
Tree	*Prosopis glandulosa*	88.9	34.8	59.17	54.2	89.0
	Condalia hookeri	66.7	26.1	19.03	17.4	43.5
	Celtis laevigata	44.4	17.4	19.22	17.6	35.0
	Celtis pallida	44.4	17.4	10.21	9.4	26.8
	Acacia minuata	11.1	4.3	1.56	1.4	5.7
	Total			109.19		
Shrub	*Celtis pallida*	66.7	37.5	12.59	46.1	83.6
	Condalia hookeri	33.3	18.8	6.10	22.4	41.2
	Ziziphus obtusifolia	33.3	18.8	3.10	11.4	30.2
	Prosopis glandulosa	22.2	12.5	3.17	11.6	24.1
	Celtis laevigata	22.2	12.5	2.33	8.6	21.1
	Total			27.29		

Table 6 – Comparison of the relative importance of species occurring in the ground layer at **Escobares**, Starr County, Texas. Freq. = Frequency, Rel. freq. = Relative Frequency, Rel. cov. = Relative Cover, Imp. Val. = Importance Value (the sum of relative frequency and relative cover).

Species	Freq.	Rel. freq.	% Cover	Rel. cov.	Imp. Val.
Celtis laevigata	44.4	11.1	2.44	26.9	38.0
Pennisetum ciliare	44.4	11.1	2.42	26.7	37.8
Chromolaena odorata	55.5	13.9	1.18	13.0	26.9
Celtis pallida	33.3	8.3	0.90	9.9	18.2
Cocculus diversifolius	33.3	8.3	0.61	6.7	15.0
Condalia hookeri	33.3	8.3	0.30	3.3	11.6
Setaria leucopila	33.3	8.3	0.10	1.1	9.4
Boerhavia scandens	22.2	5.6	0.33	3.7	9.3
Ziziphus obtusifolia	22.2	5.6	0.22	2.4	8.0
Guaiacum angustifolium	11.1	2.8	0.20	2.2	5.0
Cynodon dactylon	11.1	2.8	0.12	1.3	4.1
Opuntia engelmannii	11.1	2.8	0.11	1.2	4.0
Malvastrum coromandelianum	11.1	2.8	0.06	0.6	3.4
Chenopodium sp.	11.1	2.8	0.03	0.4	3.2
Verbena officinalis	11.1	2.8	0.03	0.4	3.2
Poaceae: Unidentified	11.1	2.8	0.01	0.1	2.9
Total			9.06		

Table 7 – Comparison of mean height (m) and species importance in the tree layer at **McManus Unit**, Texas Parks and Wildlife Department, Hidalgo County, Texas. Freq. = Frequency, Rel. Freq. = Relative Frequency, Den. = Density, Rel. Den. = Relative Density, Rel. Cov. = Relative Cover, Imp. Val. = Importance Value (the sum of relative frequency, relative density and relative cover). Density is the number per 1,000 sq. m.

Species	Height m	Freq. %	Rel. Freq.	Den.	Rel. Den.	Cover cm	Rel. Cov.	Imp. Val.
Celtis pallida	3.78	90	15.5	43	22.6	425.0	23.5	61.6
Sideroxylon celastrinum	4.13	90	15.5	46	24.2	223.2	12.3	52.0
Ulmus crassifolia	6.07	50	8.6	19	10.0	248.9	13.7	32.3
Chloroleucon ebano	4.44	20	3.4	15	7.9	276.1	15.2	26.5
Zanthoxylum fagara	3.21	50	8.6	13	6.8	106.9	5.9	21.3
Diospyros texana	4.00	60	10.3	8	4.2	66.7	3.7	18.2
Celtis laevigata	4.20	20	3.4	13	6.8	92.6	5.1	15.3
Prosopis glandulosa	6.25	30	5.2	4	2.1	116.6	6.4	13.7
Ehretia anacua	4.72	30	5.2	5	2.6	59.2	3.3	11.1
Xylosma flexuosa	3.10	10	1.7	7	3.6	48.5	2.7	8.0
Condalia hookeri	3.50	30	5.2	3	1.6	10.6	0.6	7.4
Parkinsonia aculeata	6.38	20	3.4	4	2.1	25.8	1.4	6.9
Guaiacum angustifolium	4.60	20	3.4	2	1.1	38.8	2.1	6.6
Ziziphus obtusifolia	3.13	20	3.4	3	1.6	21.6	1.2	6.2
Acacia greggii	5.55	20	3.4	2	1.1	20.0	1.1	5.6
Acacia minuata	4.95	10	1.7	2	1.1	17.2	0.9	3.7
Phaulothamnus spinescens	3.70	10	1.7	1	0.6	14.0	0.8	3.1

Table 8 – Comparison of species importance in the shrub layer at **McManus Unit**, Texas Parks and Wildlife Department, Hidalgo County, Texas. Freq. = Frequency, Rel. Freq. = Relative Frequency, Den. = Density, Rel. Den. = Relative Density, Rel. Cov. = Relative Cover, Imp. Val. = Importance Value (the sum of relative frequency, relative density and relative cover). Density is the number per 1,000 sq. m.

Appendix 3. New riparian survey sites

Species	Freq. %	Rel. Freq.	Den.	Rel. Den.	Cover cm	Rel. Cov.	Imp. Val.
Phaulothamnus spinescens	90	9.7	61	12.0	506.3	27.3	49.0
Amyris texana	100	10.8	95	18.7	305.1	16.5	46.0
Zanthoxylum fagara	100	10.8	79	15.5	221.7	12.0	38.3
Ehretia anacua	90	9.7	58	11.4	141.9	7.7	28.8
Sideroxylon celastrinum	100	10.8	43	8.4	119.1	6.4	25.6
Xylosma flexuosa	20	2.2	41	8.1	154.0	8.3	18.6
Celtis pallida	80	8.6	23	4.5	93.4	5.0	18.1
Guaiacum angustifolium	70	7.5	17	3.3	31.1	1.7	12.5
Condalia hookeri	40	4.3	14	2.8	34.4	1.9	9.0
Chloroleucon ebano	30	3.2	13	2.6	32.8	1.8	7.6
Ulmus crassifolia	20	2.2	18	3.5	32.0	1.7	7.4
Celtis laevigata	30	3.2	12	2.4	33.1	1.8	7.4
Ziziphus obtusifolia	40	4.3	6	1.2	28.0	1.5	7.0
Fraxinus berlandieriana	10	1.1	14	2.8	35.6	1.9	5.8
Forestiera angustifolia	30	3.2	5	1.0	29.6	1.6	5.8
Sapindus saponaria	30	3.2	3	0.6	7.6	0.4	4.2
Malphiga glabra	20	2.2	4	0.8	21.8	1.2	4.2
Castela erecta	10	1.1	1	0.2	18.0	1.0	2.3
Amyris madrensis	10	1.1	1	0.2	4.5	0.2	1.5
Diospyros texana	10	1.1	1	0.2	2.0	0.1	1.4

Table 9 - Comparison of species importance in the ground layer at **McManus Unit**, Texas Parks and Wildlife Department, Hidalgo County, Texas. Freq. = Frequency, Rel. Freq. = Relative Frequency, Rel. Cov. = Relative Cover, Imp. Val. = Importance Value (the sum of relative frequency and relative cover).

Species	Freq. %	Rel. Freq.	Cover %	Rel. Cov.	Imp. Val.
Chromolaena odorata	46	7.1	7.51	27.7	34.8
Panicum maximum	32	5.0	5.42	20.0	25.0
Setaria leucopila	52	8.1	4.38	16.1	24.2
Tamaulipa azurea	44	6.8	2.63	9.7	16.5
Dicliptera sexangularis	34	5.3	1.52	5.6	10.9
Salvia coccinea	46	7.1	0.46	1.7	8.8
Abutilon trisulcatum	36	5.6	0.52	1.9	7.5
Cocculus diversifolius	38	5.9	0.27	1.0	6.9
Ehretia anacua	24	3.7	0.52	1.9	5.6
Zanthoxylum fagara	24	3.7	0.40	1.5	5.2
29 additional species Total			27.13		

APPENDIX 4

Regional Ecological Resource Assessment of the Rio Grande Riparian Corridor: A Multidisciplinary Approach to Understanding Anthropogenic Effects on Riparian Communities in Semiarid Environments

Investigators

Jay Raney[1], Principal Investigator,

Melba Crawford[2], Frank Judd[3], and Gene Paull[4], Co-Principal Investigators

Robert Lonard[3], Amy Neuenschwander[2], Thomas Tremblay[1], William White[1]

Institutions

Bureau of Economic Geology[1] and Center for Space Research[2]

The University of Texas at Austin

The University of Texas-Pan American[3]

The University of Texas at Brownsville[4]

U.S. Environmental Protection Agency

STAR Regional Scale Analysis and Assessment

EPA Assistance Id. No. R 827677-01-0

UPWARD SCALING IN REMOTE SENSING AND CLASSIFICATION OF RIPARIAN VEGETATION, LOWER RIO GRANDE VALLEY, TEXAS

Melba Crawford, Bill White, Tatiana Bacheva, Tom Tremblay, Jay Raney, Frank Judd, Bob Lonard and Gene Paull

Objectives

- Delineate riparian vegetation using remotely sensed data supported by field surveys
- Classify vegetation communities based on deciduous and evergreen species composition
- Scale upward in classification from local high resolution remotely sensed data to regional low resolution remotely sensed data
- Analyze results to evaluate accuracy of classification and methods

Methods

Algorithm classification training sites were delineated using:

1. Color Infrared (CIR) digital orthophoto quandrangles (DOQ's) with 1 m resolution

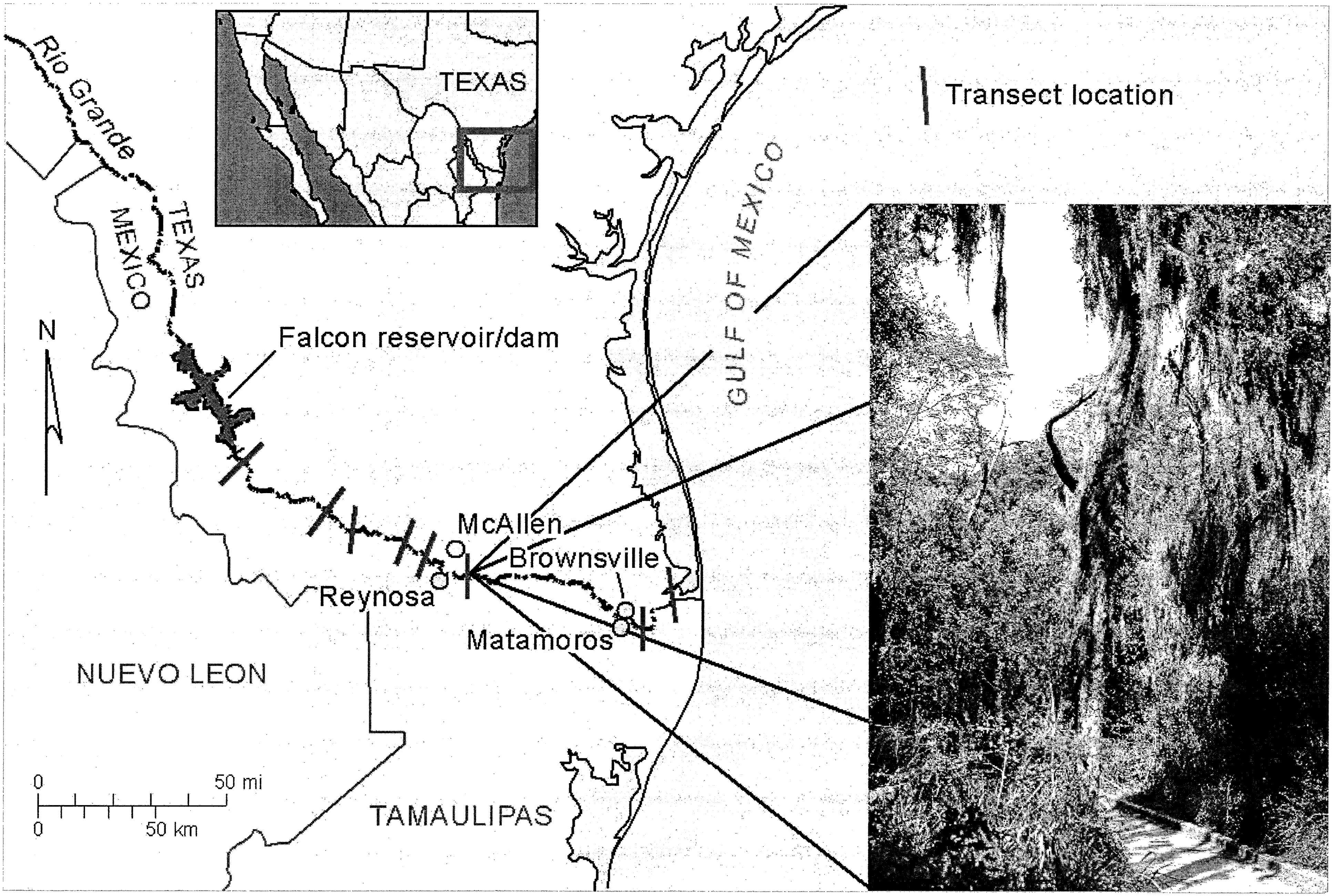
2. High-resolution spectrally calibrated hyperspectral data (HYMAP) with 3 to 7 m resolution

3. Field surveys in which vegetation communities were classified to species level

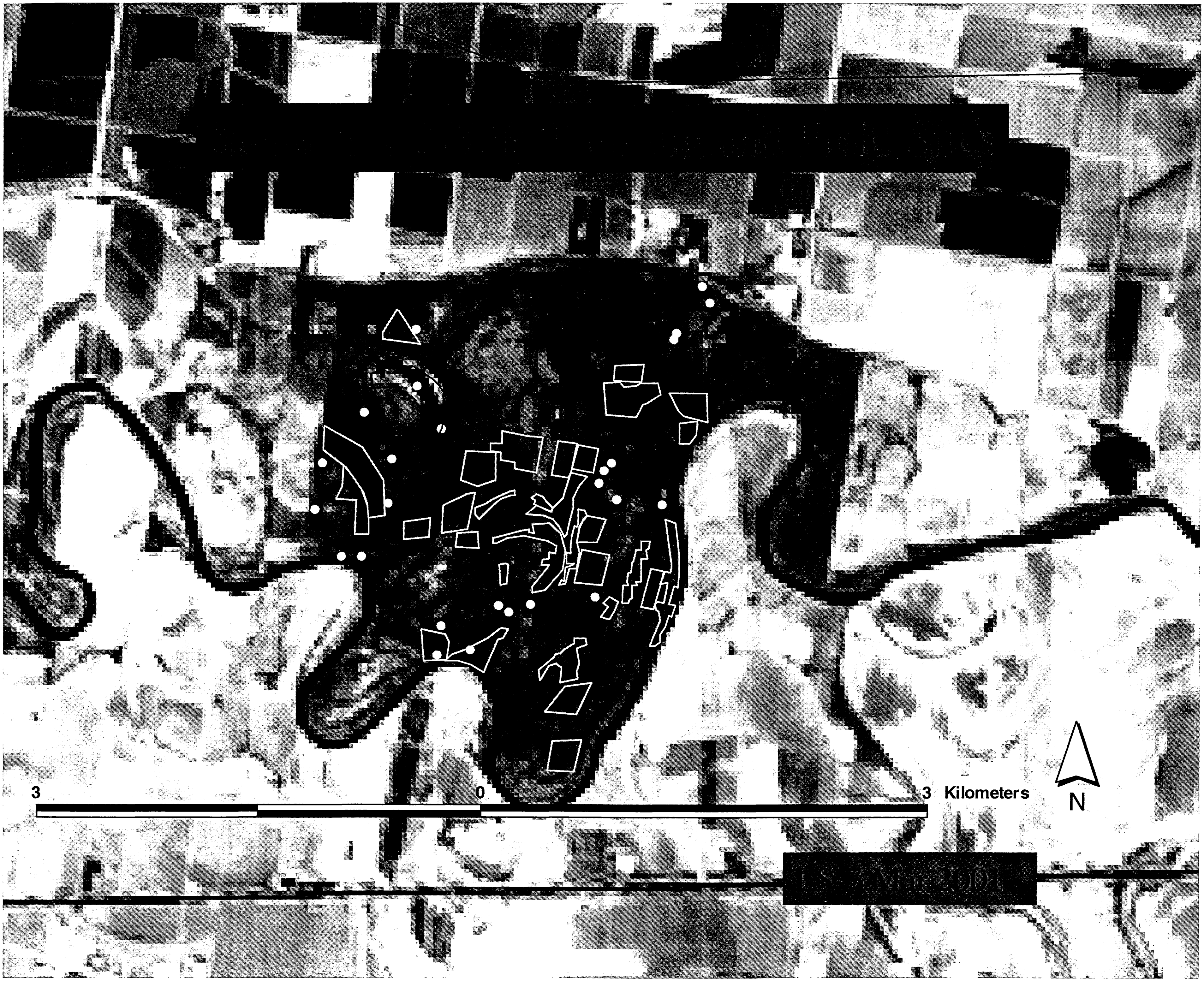
More than 10 iterations of the classification were completed using 2 HYMAP and 4 Landsat scenes

Methods ……

- High-resolution hyperspectral data from HYMAP, acquired of the Santa Ana National Wildlife Refuge, were analyzed with respect to
  - (1) 27 ground-truth sites in which dominant vegetation had been determined
  - (2) 35 training sites classified visually from large scale DOQ's
- The resulting classification was used as baseline data against which to measure the accuracy of Landsat 7 classification results.



Santa Ana National Wildlife Refuge



3
0
3 Kilometers
N

Riparian Classes

- Five classes of vegetation communities were defined based on evergreen and deciduous species and combinations of the two.

- Vegetation composition was determined from field surveys and interpretation of high-resolution, digital CIR aerial photos (DOQ's) acquired during winter months.

- Classification is modeled after the USFWS National Wetlands Inventory program, in which riparian vegetation inventory and mapping conventions were developed for the Western United States.

USFWS Classification

- Classification is hierarchical, with the Riparian System having two subsystems
  - Lentic
  - Lotic
- Subsystems are subdivided into classes
  - Forested
  - Scrub/shrub
- Class have three subclasses
  - Deciduous
  - Evergreen
  - Mixed

Five sub-classes were delineate in this project

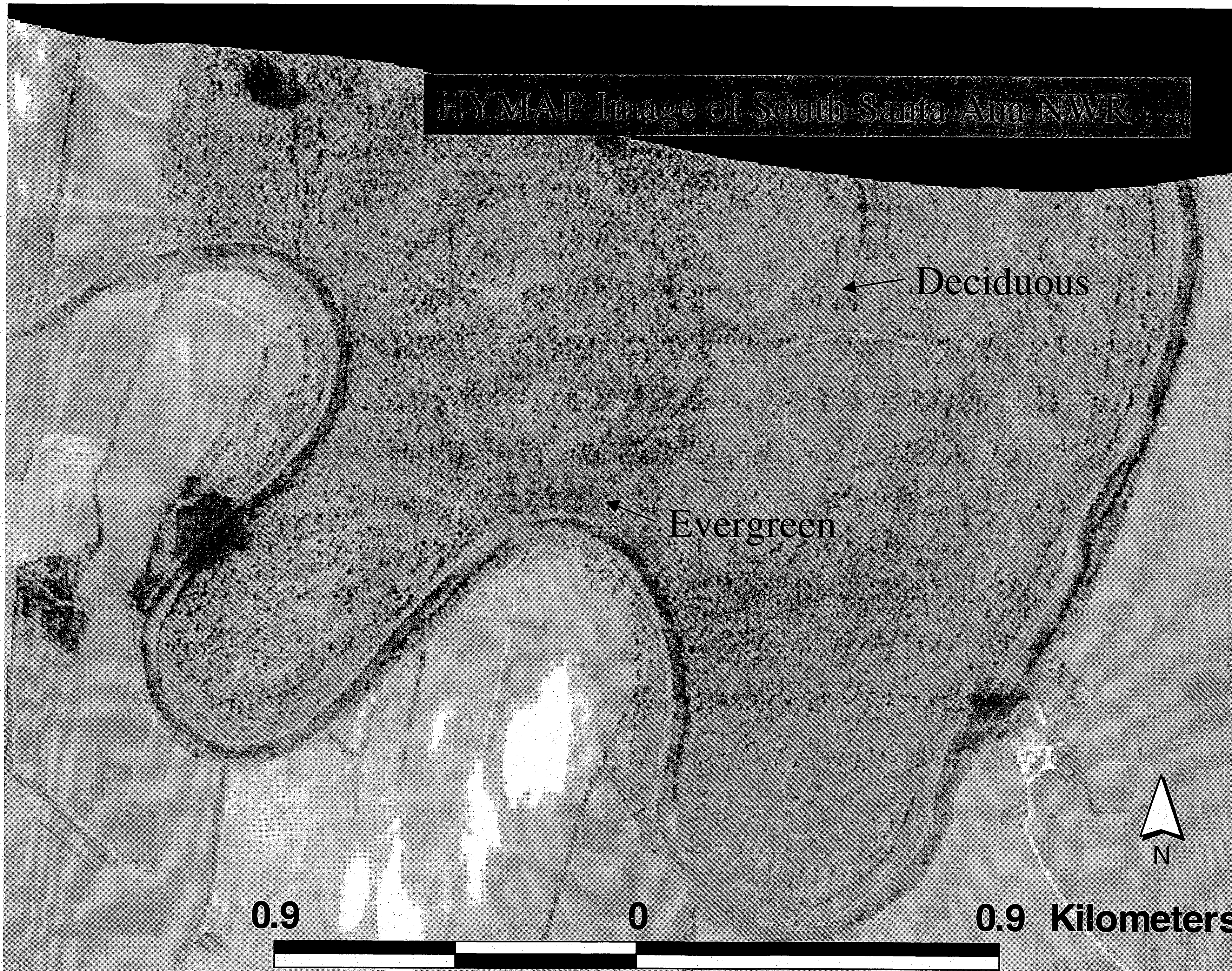
1. Evergreen
2. Deciduous
3. Mixed, evergreen and deciduous co-dominant
4. Mixed, evergreen dominant
5. Mixed, deciduous dominant

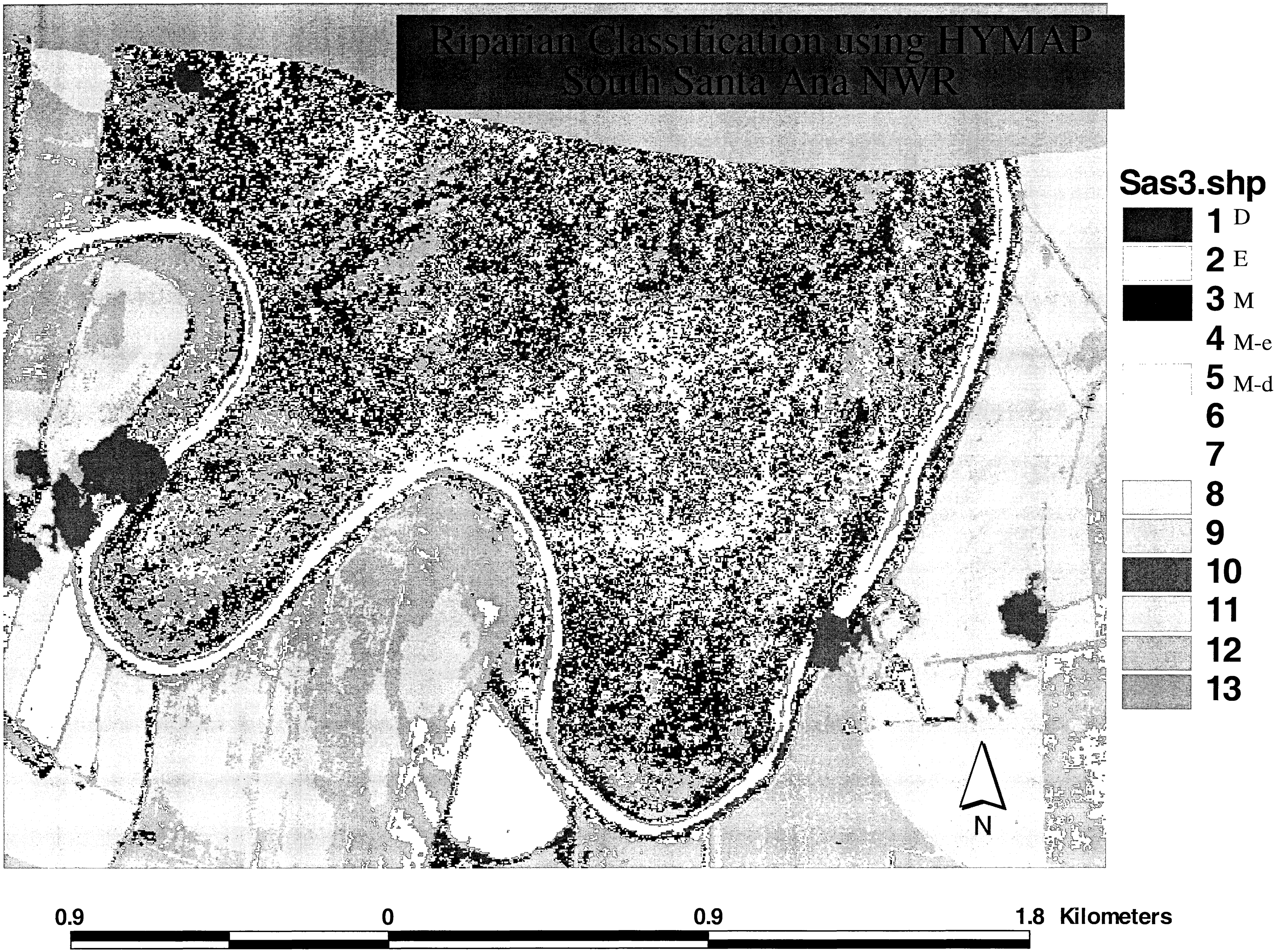
Typical Evergreen Species

- Texas ebony (*Chloroleucon ebano*)
- Anacua (*Ehretia anacua*)
- Granjeno (*Celtis pallida*)
- La coma (*Sideroxylon celastrina*)
- Tepeguaje (*Leucaena pulverulenta*)

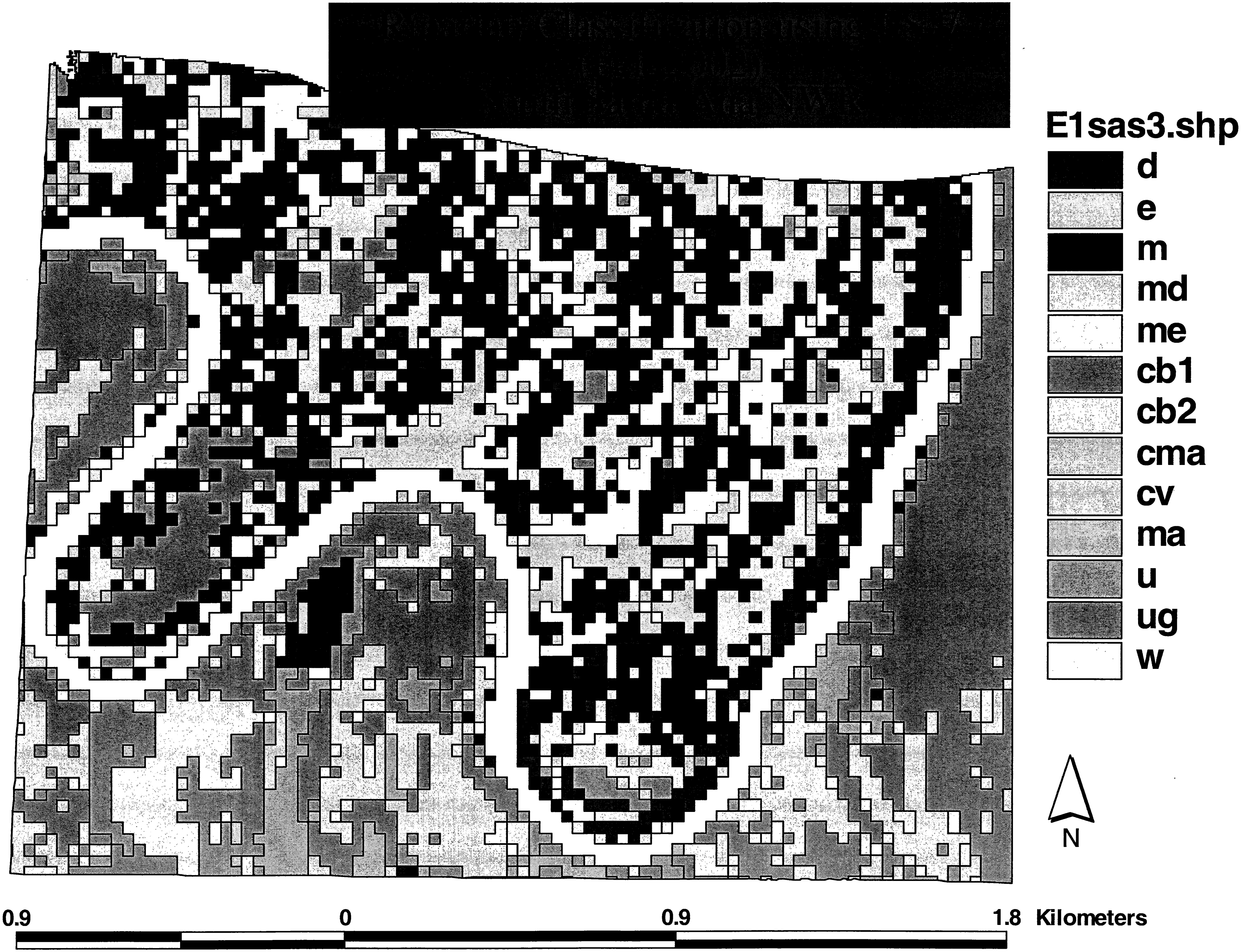
Typical Deciduous Species

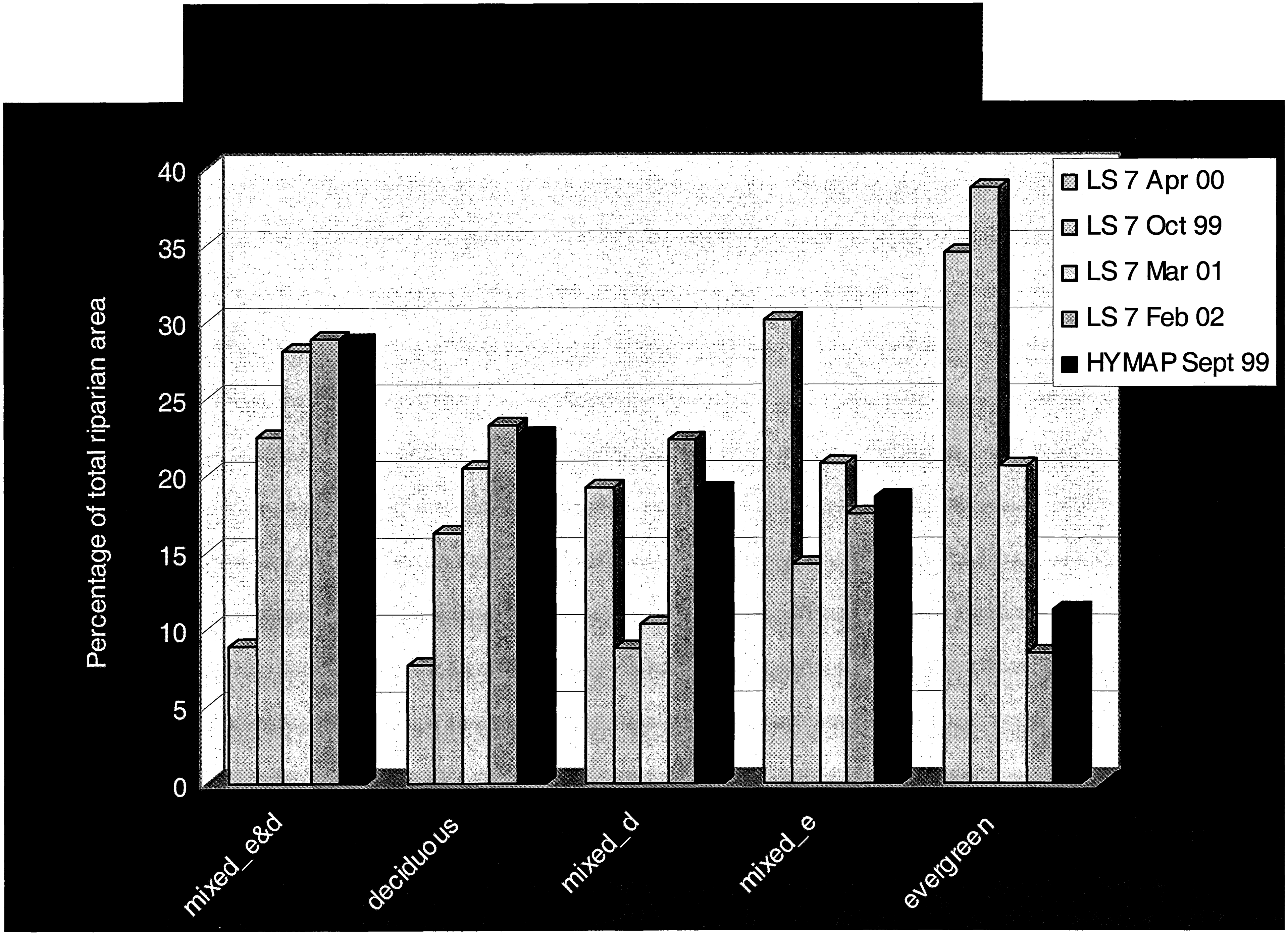
- Hackbery (*Celtis laevigata*)
- Cedar elm (*Ulmus crassifolia*)
- Mesquite (*Prosopis glandulosa*)
- Black willow (*Salix nigra*)
- Retama (*Parkinsonia aculeata*)
- Texas persimmon (*Diospyros texana*)
- Rio Grande ash (*Fraxinus berlandieriana*) (deciduous, or semi-evergreen).

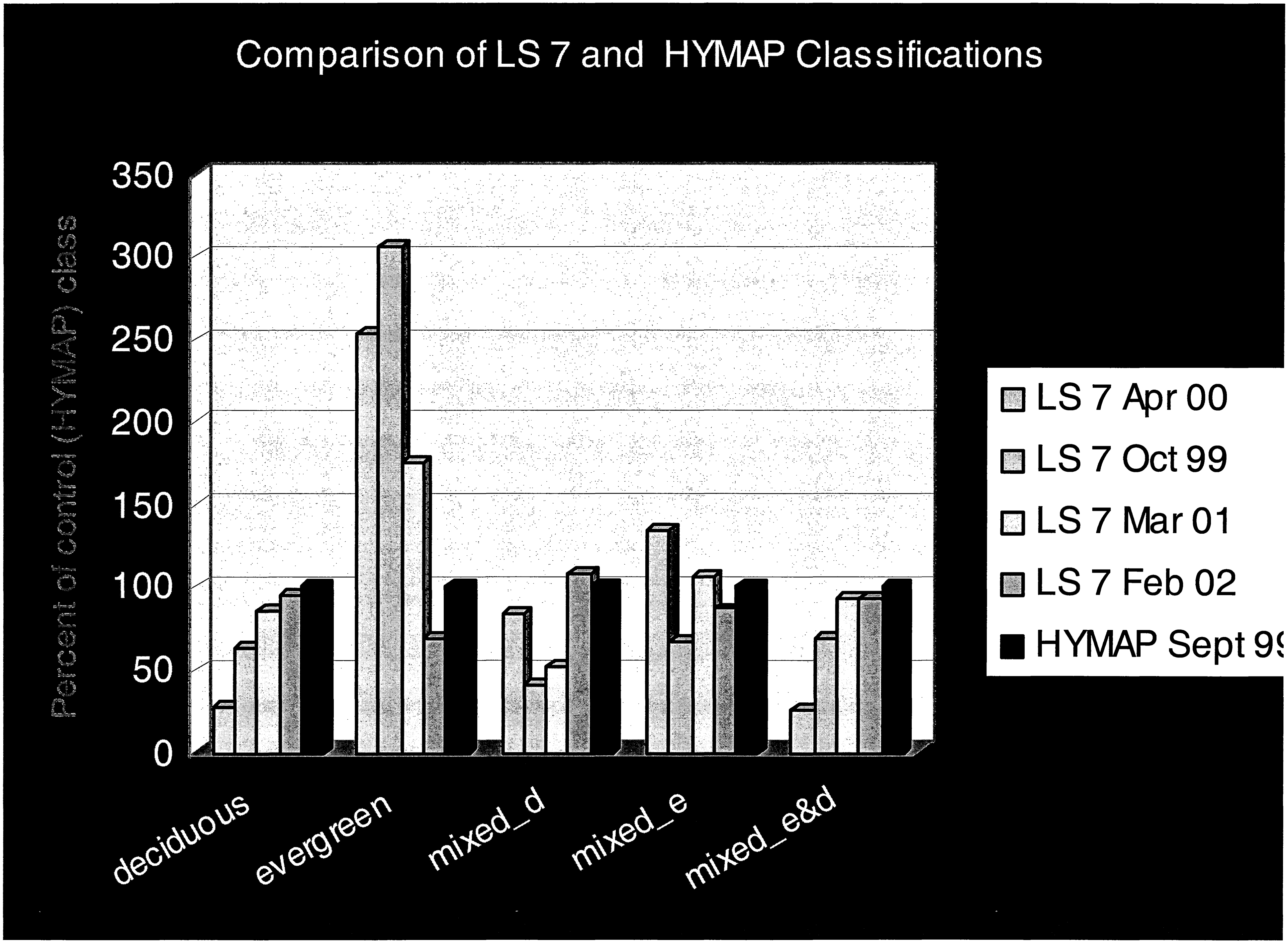

HYMAP Image of South Santa Ana NWR
Deciduous
Evergreen
N
0.9
0
0.9 Kilometers



Riparian Classification using HYMAP
South Santa Ana NWR
Sas3.shp
1 D
2 E
3 M
4 M-e
5 M-d
6
7
8
9
10
11
12
13
N
0.9
0
0.9
1.8 Kilometers


E1sas3.shp
d
e
m
md
me
cb1
cb2
cma
cv
ma
u
ug
w
N
0.9
0
0.9
1.8 Kilometers


Percentage of total riparian area
0
5
10
15
20
25
30
35
40
mixed_e&d
deciduous
mixed_d
mixed_e
evergreen
LS 7 Apr 00
LS 7 Oct 99
LS 7 Mar 01
LS 7 Feb 02
HYMAP Sept 99


Comparison of LS 7 and HYMAP Classifications
Percent of control (HYMAP) class
350
300
250
200
150
100
50
0
deciduous
evergreen
mixed_d
mixed_e
mixed_e&d
LS 7 Apr 00
LS 7 Oct 99
LS 7 Mar 01
LS 7 Feb 02
HYMAP Sept 99

Results

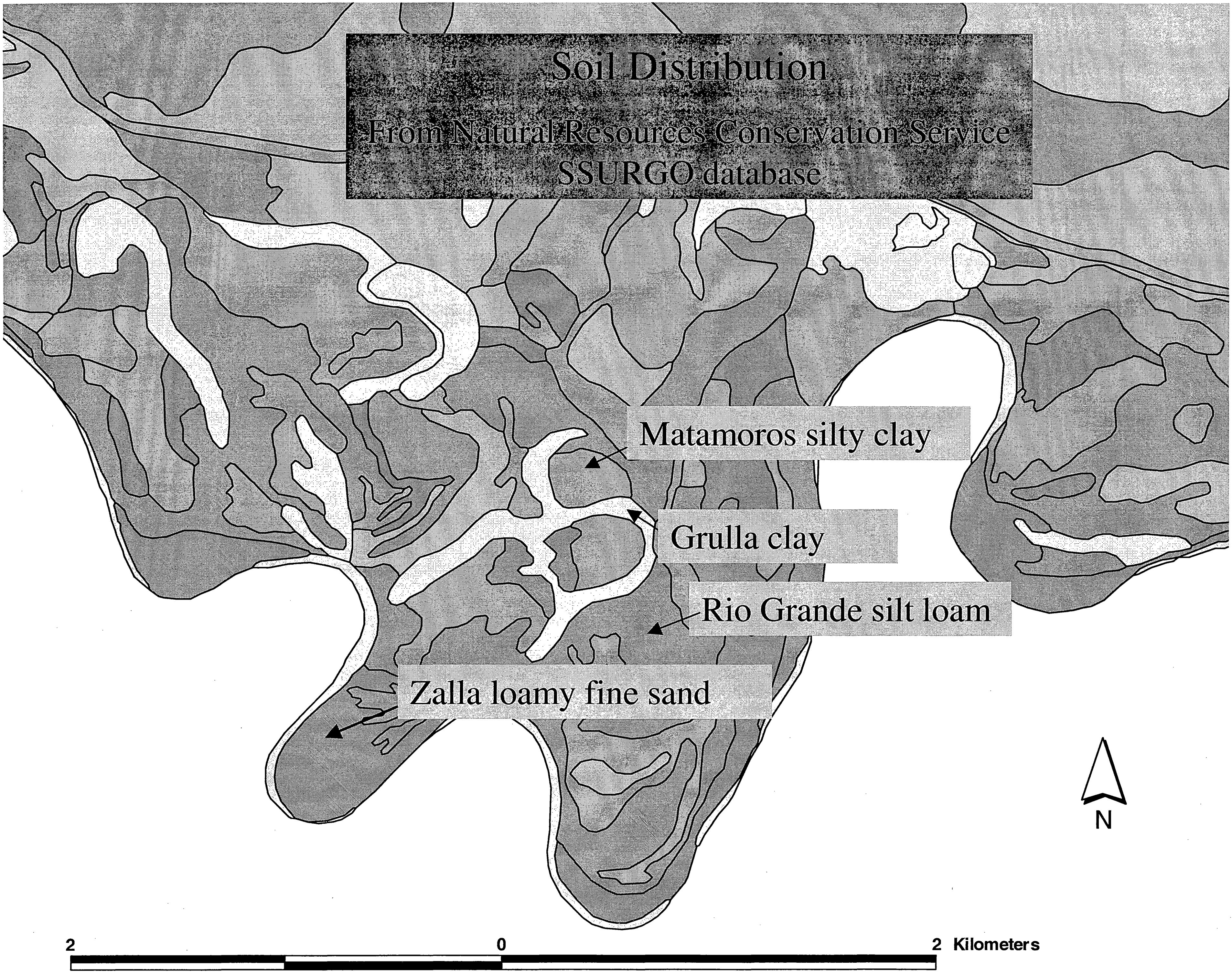
- Good classification accuracies were achieved in scaling upward from DOQ's to the hyperspectral data in the refuge.
- Classes and spatial trends were relatively well defined.
- Poorer results were achieved in scaling upward from hyperspectral data to Landsat 7 TM data and degraded further when extended beyond the refuge.
- Although general trends in vegetation communities were defined, boundaries between classes were less distinct and there was a larger scattering of classes.
- Improved results were achieved by augmenting the training sites and updating parameter estimates.
- Classification of riparian communities using Landsat 7 data outside the refuge had mixed results.

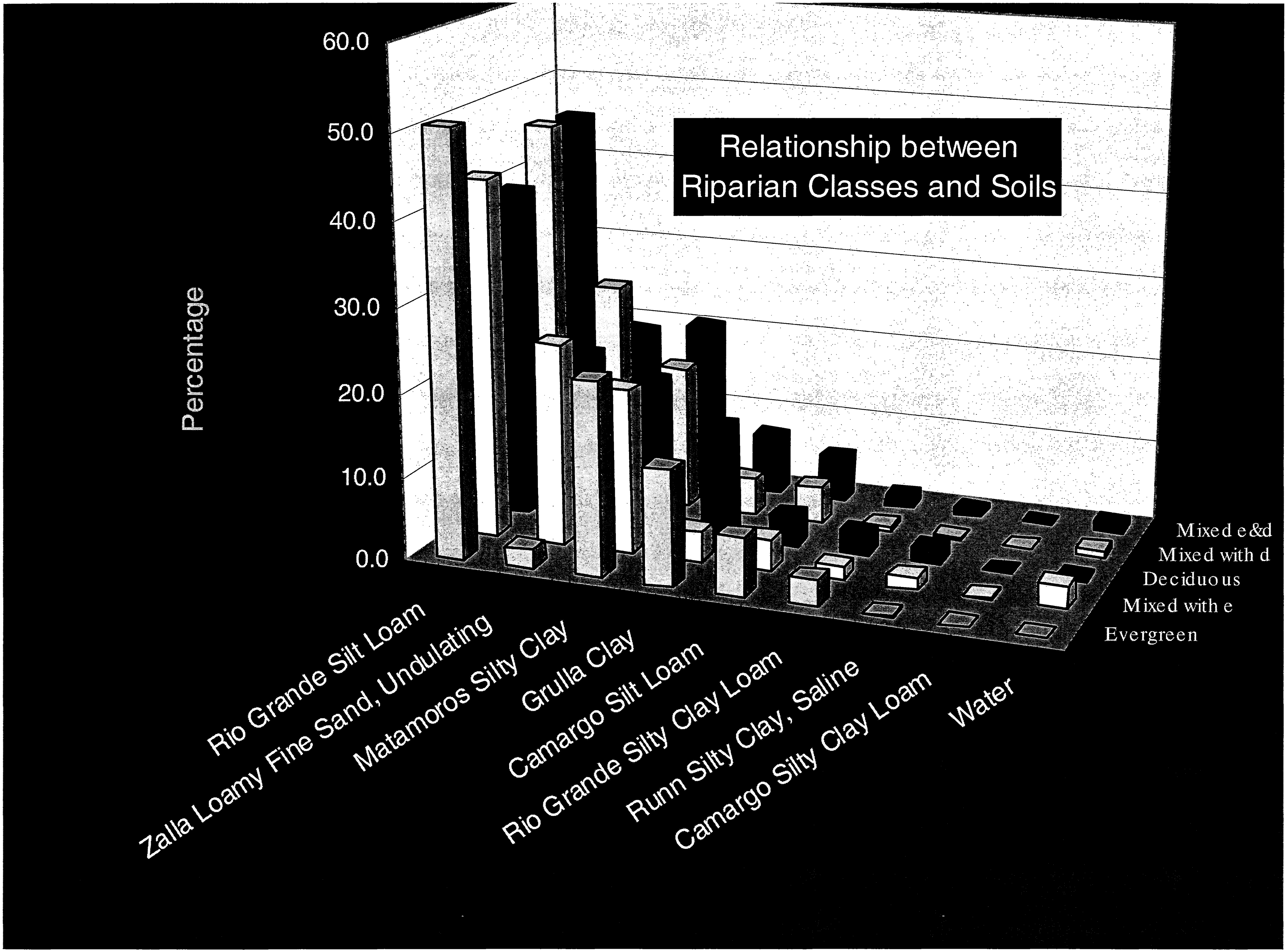
Results….

- Landsat imagery acquired in March and February consistently provided better results for all classes compared to imagery acquired in June and October.
- This was expected because of the higher spectral contrast between deciduous and evergreen vegetation during winter months when deciduous trees have dropped their leaves

Riparian Vegetation and Soils

- There is a strong correlation between riparian vegetation and soils
- Along the Rio Grande in Cameron County, for instance, although 17 different soils were associated with riparian vegetation, 3 soils made up more than 60% of the association (Rio Grande silt loam—22%; Zalla loamy fine sand—21%, and Matamoros silty clay—18%).
- There is a close association between these soils and Riparian vegetation classes in the Santa Ana NWR


Soil Distribution
From Natural Resources Conservation Service
SSURGO database
Matamoros silty clay
Grulla clay
Rio Grande silt loam
Zalla loamy fine sand
N
2
0
2 Kilometers



Relationship between
Riparian Classes and Soils
Percentage
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Rio Grande Silt Loam
Zalla Loamy Fine Sand, Undulating
Matamoros Silty Clay
Grulla Clay
Camargo Silt Loam
Rio Grande Silty Clay Loam
Runn Silty Clay, Saline
Camargo Silty Clay Loam
Water
Mixed e&d
Mixed with d
Deciduous
Mixed with e
Evergreen

Relationship between Riparian Classes and Soils

	Riparian Classes				
Soils	Evergreen	Mixed with e	Deciduous	Mixed with d	Mixed e&d
Rio Grande Silt Loam	50.6	43.0	39.5	45.8	45.2
Zalla Loamy Fine Sand, Undulating	2.2	24.2	20.5	26.6	18.9
Matamoros Silty Clay	23.2	19.6	18.2	17.3	20.3
Grulla Clay	13.9	3.6	13.6	4.4	7.1
Camargo Silt Loam	6.9	3.7	3.6	4.3	5.4
Rio Grande Silty Clay Loam	3.1	1.6	2.6	0.6	1.5
Runn Silty Clay, Saline	0.1	1.4	1.7	0.2	0.6
Camargo Silty Clay Loam	0.0	0.1	0.0	0.0	0.0

Conclusions

- Hyperspectral data is superior to multispectral data in classifying riparian vegetation
- High resolution CIR aerial photographs taken in winter months provide a good platform on which to select sites for training algorithms
- Good classification results for deciduous and evergreen species were acquired from Hyperspectral data acquired in summer months
- Scaling upward from hyperspectral to multispectral data was best achieved using LS-7 imagery acquired in winter months