Integration of Remote Sensing and Spatial Information Technologies for Mapping Black Mangrove on the Texas Gulf Coast

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ABSTRACT


Black mangrove [Avicennia germinans (L.) L.] occurs at several locations along the Texas gulf coast. A hard freeze in December 1989 severely damaged this species, but the extent of damage has not been determined. Airborne color-infrared (CIR) video imagery was used with global positioning system (GPS) and geographic information system (GIS) technologies for distinguishing and mapping the current distribution of black mangrove. Black mangrove populations could be easily distinguished on CIR video imagery. The integration of a GPS with the video imagery permitted latitude/longitude coordinates of black mangrove populations to be recorded on each image. The GPS coordinates were entered into a GIS to map black mangrove populations along the Texas coast. Major black mangrove concentrations near Port Isabel-South Bay and Port Aransas on the lower and lower-mid Texas coast, respectively, had fully recovered from the freeze. A remnant population of an historical black mangrove concentration on the upper-mid Texas coast near Port O'Connor, that was devastated by a 1983 freeze, was severely damaged and reduced in number by the 1989 freezes. The integration of videography, GPS, and GIS are valuable tools that can enable coastal resource managers to develop regional maps showing the distribution of black mangrove over large areas.

ADDITIONAL INDEX WORDS. Color-infrared videography, geographic information system, global positioning system, Texas gulf coast.

INTRODUCTION

Black mangrove [Avicennia germinans (L.) L.], a widespread species of the American tropics and subtropics, is the only mangrove species that occurs along the Texas gulf coast (CORRELL and JOHNSTON, 1970). SHERROD and McMILLAN (1981) reported on the distribution of black mangrove along the Texas coast and suggested that three major mangrove concentrations, i.e., Calvallo Pass in Calhoun County, Harbor Island in Nueces County, and Port Isabel-South Bay area of Cameron County, represented areas of continuous mangrove occurrence throughout the twentieth century. During periods of favorable weather, distribution expanded from these three centers and during unfavorable periods the populations contracted (SHERROD and McMILLAN, 1981).

In December 1983, a cold front moved through Texas dropping air temperatures throughout the coastal area to well below freezing. At Brownsville near the southern tip of Texas, a low of −6.1°C was recorded, and there were 54 consecutive hours below 0°C (SHERROD et al., 1986). Areas along the mid and upper Texas Coast experienced lower extreme temperatures and longer durations of below freezing temperatures. Black mangrove was seriously damaged by this freeze (LONARD and JUDD, 1985; SHERROD et al., 1986). A remote sensing survey with color-infrared (CIR) film and subsequent ground truthing (EVERITT and JUDD, 1989) of the Texas coast in the late 1980's showed that black mangrove populations near Port Isabel-South Bay and Harbor Island were actively growing and had fully recovered from the 1983 freeze, but the concentration near Calvallo Pass was estimated to be < 5% of what it had been prior to the 1983 freeze (SHERROD and McMILLAN, 1986).
A second severe freeze occurred along the Texas Coast in December 1989 with two freezing episodes reported at Brownsville; one with 33.75 consecutive hours below freezing and a second with 16.75 consecutive hours below freezing. A minimum temperature of $-8.4^\circ C$ was recorded during the first episode and $-8.9^\circ C$ in the second episode (United States National Weather Service, Brownsville, Texas; LONARD and JUDD, 1991). Additional northern coastal areas had lower temperatures and longer durations below freezing. LONARD and JUDD (1991) reported that black mangrove plants near Port Isabel were as severely damaged by the 1989 freeze as they had been by the 1983 freeze (LONARD and JUDD, 1985).

Color-infrared aerial photography has been used extensively to document the extent and distribution of black mangrove (REARK, 1975; SHERROD and McMILLAN, 1981; EVERITT and JUDD, 1989). Recently, CIR aerial video imagery has also proven effective for distinguishing black mangrove (EVERITT et al., 1991a). Video imagery has many attributes that make it attractive for remote sensing, but the most prominent are its near-real-time availability of imagery, cost effectiveness, and the electronic format of data (EVERITT et al., 1991a).

Recently, aerial videography and global positioning system (GPS) technology have been integrated and shown to be useful tools to detect and monitor insect activity over forested areas (BOBBE and ISHIKAWA, 1992; MYHRE, 1992). The latitude/longitude data provided by the GPS were entered into a geographic information system (GIS) to georeference forest pest problems (MYHRE, 1992). EVERITT et al. (1993, 1994) used aerial videography and GPS technology to detect weed and brush infestations on rangelands and entered the georeferenced data into a GIS to map noxious plant populations over an extensive area.

The objectives of this study were: (1) to use airborne videography (and ground truthing) to determine the effects of the 1989 freeze on black mangrove along the Texas Gulf Coast; and (2) incorporate videography with GPS and GIS technologies for mapping the distribution of black mangrove.

**MATERIALS AND METHODS**

Airborne multispectral video integrated with a GPS was used to detect and map black mangrove along the Texas gulf coast from Galveston County to Cameron County. Imagery of black mangrove was obtained with a high resolution multispectral video system composed of charge-coupled device (CCD) cameras, a color encoder, and super (S)-VHS recorders that provide high quality CIR imagery (EVERITT et al., 1991b). Video imagery was acquired with a fixed-wing Cessna T206 aircraft at altitudes ranging from 610 m (2,000 ft) to 915 m (3,000 ft). Imagery was acquired on September 29, 1993 between 1100 and 1600 hrs under sunny conditions.

A Trimble* Transpak II GPS was integrated with the video system to obtain location coordinates of black mangrove populations. The GPS was equipped with a navigation system which constantly received data from GPS satellites and readily calculated and displayed continuously the flight direction (bearing), ground speed, altitude, time, and latitude/longitude coordinates of the aircraft location above the ground. A Complix interphasor was used with the GPS which permitted the transfer and recording of this continuous information on the last two lines of the video imagery. The latitude/longitude coordinates on the video correspond to the approximate center of each scene. The black mangrove location coordinates were obtained from the video scenes and then entered into the computer manually. The accuracy of the GPS was approximately ±100 m from the center coordinates of each video scene, which was adequate for detecting black mangrove populations. A differential GPS can provide sub-meter accuracy, but these systems are costly.

Personal computer ATLAS-GIS software was used to generate a map of the gulf coast counties of Texas and two detail coastal portion maps of Cameron and Nueces counties based on the 1990 post census TIGER/Line files for the State of Texas. The U. S. Census Bureau developed and trademarked a machine readable referenced map base called TIGER (Topologically Integrated Geographic Encoding and Referencing) for the 1990 census. The TIGER map-based system was constructed using USGS 1:100,000 scale digital line graph maps. The ATLAS-GIS maps provided greater detail of the counties such as major highways, roads, hydrography and other landmarks. These maps were produced to geographically map the black mangrove locations in the counties using the airborne survey GPS data.

* Mention of company name is for the reader's benefit and does not constitute endorsement of a particular product by the U. S. Department of Agriculture over others that may be commercially available.
Ground truth surveys were made in the fall of 1993 at several sites near Port Isabel—South Bay—Boca Chica (Cameron County), Cavallo Pass near Port O'Connor (Calhoun County), Galveston Island (Galveston County), and Harbor Island near Port Aransas (Nueces County) where the aerial video imagery was acquired to verify the presence of black mangrove populations. Plant height measurements were obtained from black mangrove populations near Port Isabel, Port O'Connor, and Harbor Island. Twenty-five plants were measured at each location. Ground photographs were taken to aid video imagery interpretation.

RESULTS AND DISCUSSION

Figures 1A and 1B show CIR video images of black mangrove communities near South Bay and Harbor Island, respectively. The arrows on each print point to the distinct bright red image response of black mangrove compared with the light to dull shades of red and magenta of other associated vegetation. Dry bare soil has a whitish image tone, wet bare soil and litter have a gray tone, and water has various shades of blue. The GPS data is displayed at the bottom of the video scenes. The integration of the latitude-longitude coordinates with the video images is useful to locate black mangrove populations over remote and inaccessible areas. Aerial videographic data showed that black mangrove occurred at 23 locations on the lower Texas coast (Port Isabel—South Bay—Boca Chica) and 15 locations on the lower-mid Texas Coast (Harbor Island). Ground truth reconnaissance confirmed the presence of black mangrove at all locations. The plants appeared to have fully recovered from the 1989 freeze, were actively growing, and had a good fruit crop. At the Harbor Island site, plants ranged in height from 96 to 182 cm with a mean height of 125 cm. Black mangrove plants measured from a population near Port Isabel ranged in height from 97 to 178 cm, with a mean height of 133 cm.

Analysis of the video imagery obtained of the barrier islands in the Cavallo Pass area on the upper-mid Texas coast suggested that few black mangrove plants remained in this area. Ground visits to the area confirmed that none of the major mangrove communities remained there. However, several scattered plants were found around the perimeter of the islands with fewer plants found in the interior of the islands. Plants ranged in height from 54 to 140 cm, with a mean height of 87 cm. We observed no fruit on any of the plants. Based on a comparison of the current video imagery and ground observations to earlier maps, photography, and ground data of this area (Sherrod and McMillan, 1981; Everett and Judd, 1989), the 1989 freeze reduced mangrove populations in the area to <2% of what they had been prior to the 1983 freeze. The 1983 freeze reportedly reduced these populations to <5% of what they were before that freeze (Everitt and Judd, 1989).

No black mangrove plants could be detected in imagery acquired of Galveston Island on the upper Texas coast; however, a few isolated plants <75 cm tall were found in a ground visit. No fruit was observed on these plants. Black mangrove had been previously reported from this area (Sherrod and McMillan, 1981), but apparently the freezes of 1983 and 1989 have nearly eliminated this species from the upper Texas coast.

Figure 2 shows a regional GIS TIGER map of the entire Texas gulf coast. The approximate locations where black mangrove occurs are denoted: (1) Port Isabel-South Bay; (2) Harbor Island; (3) Cavallo Pass; and (4) Galveston Island. A detailed TIGER map of the Port Isabel-South Bay area is shown in the lower left part of the figure. The GPS latitude-longitude data provided on the video imagery of the area has been integrated with the GIS to georeference populations of black mangrove. The triangles depict the 23 locations where black mangrove occurs in this area. A detailed map (right center) is also shown for the Harbor Island area depicting the GPS georeference data for the 15 locations where black mangrove occurs in this area. A local site map showing even greater detail of a highlighted area in the Harbor Island area is shown in the lower right portion of the figure. This capability of the GIS software is useful for obtaining more specific details on areas of interest. No detailed maps are provided for the Cavallo Pass and Galveston Island areas since few.
black mangrove plants occur there. The integration of the GPS with GIS technology enables the coastal zone manager to develop regional maps showing where black mangrove populations occur over large areas.

CONCLUSIONS

These results demonstrated that CIR aerial video imagery was a useful tool to distinguish black mangrove populations along the Texas coast. We showed that two major concentrations of black
mangrove remained along the Texas coast: Harbor Island and Port Isabel–South Bay areas. Populations in these two areas had recovered from the 1989 freeze and were actively growing. Only scattered black mangrove plants remained in a historical concentration near Cavallo Pass (Sherrod and McMillan, 1981). This population had been devastated by the 1983 freeze. The 1989 freeze severely damaged or killed many of the plants that had survived the earlier freeze.

The integration of videography, GPS, and GIS are valuable and cost-effective tools. These technologies enable coastal resource managers to develop regional maps depicting where black mangrove populations occur over large areas. The video imagery can provide a means of determining density estimates of black mangrove populations for specific locations and can serve as a permanent geographically-located image data base to monitor future contraction or spread over time.

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LITERATURE CITED


