Differentiating Bottomland Tree Species with Multispectral Videography

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Abstract

Large-scale multispectral, multitemporal aerial video images were evaluated for speciation of bald-cypress and several species of bottomland hardwoods. Images were acquired with a multispectral video system, including three bandpass filters centered at 550, 800, and 1000 nm, from an altitude of 305 m. The ground-level dimension of the video image pixels was 0.329 m. Images were statistically analyzed with two supervised classification methods (minimum distance and maximum likelihood). The minimum-distance classifier yielded statistically similar results to the maximum likelihood classifier while requiring much less time. Multitemporal imagery increased classification accuracies on the order of 10 percent. Average classification accuracy for individual trees on all plots was 70 percent.

Introduction

Forest Inventory and Videography

Efficient inventory is essential for effective management of forestland resources. The agency in the United States most concerned with forestland inventories is the USDA Forest Service. The Forest Service currently monitors the forestlands of the U.S. every 10 years in its Continuous Forest Inventory (CFI) program. The Southern Forest Experiment Station of the Forest Service manages inventories for the southeastern region of the United States. Within Louisiana, which is under Southern Forest Experiment Station jurisdiction, the Atchafalaya River Basin is a very important wetland region supporting a wide variety of wetland ecosystems from bottomland hardwoods, to forested swamps, to coastal marshes. Inventory of this area by the Forest Service's survey crews is especially difficult because access to plots is often by boating or wading through inundated understory for up to 1.6 km along a constant azimuth. Measurement-crew production is usually one-third to one-half that obtained under normal conditions, so inventory costs are much greater. Because of these factors, more frequent inventory updates are not economically justifiable with standard techniques.

The desire for more frequent updates has fueled an interest in remote sensing for use in the Basin. Videography has been employed only recently in forestry applications. Vlcek (1983) reported that the use of color videography enhanced forest type-mapping. Hazard (1987) reported results showing significant improvement in spectral separation of vegetative classes in comparison with results obtained by photointerpretation of Aerochrome IR photography. Work has been done more recently to further develop multispectral remote video systems for forestry applications (King and Vlcek, 1990).

Advantages of aerial videography have been listed by Meisner and Lindstrom (1985) among others. The advantages include potential for immediate digital analysis, low cost, no time required for film processing, and real-time equipment adjustment. The solid-state charge-coupled device (CCD) imaging sensors used in modern video cameras have greater radiometric resolution than either photographic film or vidicon cameras (Lillesand and Kiefer, 1987), and they have a relatively linear response to irradiance compared to film (King, 1988). Other beneficial features are the ability to make audio notations on video tape which can aid subsequent location of a particular area on the imagery (Thomasson *et al.*, 1988), and the fact that video imagery is not affected by tonal variability caused by differences in film processing (Thomasson, 1989).

Objectives

The Atchafalaya Basin (hereafter referred to as the Basin) was selected by the Forest Service's Southern Forest Experiment Station as a pilot study site for evaluating the accuracy of multispectral aerial videography in the determination of species of bottomland trees, and for developing volume estimates from photogrammetric and regression methods applied to the videography. This report focuses on the first part of the study, i.e., identification of individual trees in large-scale videography.

Materials and Methods

Study Site

The Basin is located in south central Louisiana (Figure 1), and was formed as the natural floodplain of the Atchafalaya River. By 1965, approximately 332,000 hectares of the floodplain were leveed by the Army Corps of Engineers into a floodway designed to provide relief to the Mississippi River during flood season. Thus, much of this region is under water from December to May.

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Figure. 1. The Atchafalaya Basin in relation to the state of Louisiana.

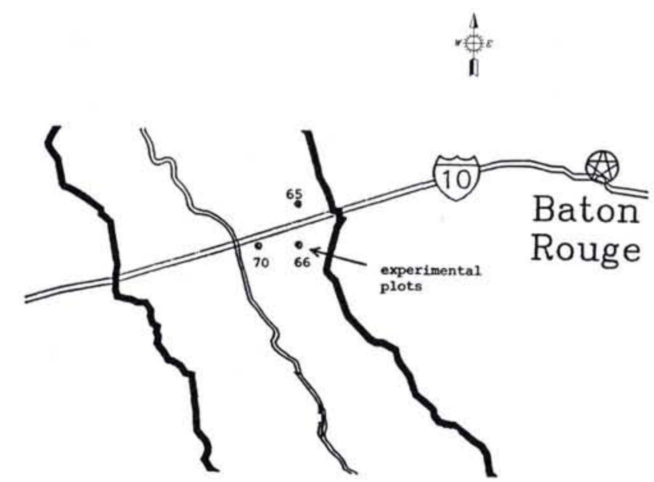

Figure. 2. Relative locations of plots under study.

Three plots, chosen primarily for their accessibility, were considered in the aerial missions. These forested CFI measurement plots, designated here as 65, 66, and 70, were variable-size plots spaced on a 4.8-kilometre (km) square grid (Figure 2). Plot 66 was 4.8 km from the other two plots, while plots 65 and 70 were 6.8 km apart. In the CFI program, merchantable species within the plots had been measured intensively, and plot conditions had been assumed to represent a 23.3 square km area surrounding the plot.

Bald-cypress (*Taxodium distichum* (L.) Rich.), black willow (*Salix nigra* Marsh.), green ash (*Fraxinus pennsylvanica* Marsh.), and water tupelo (*Nyssa aquatica* L.) constituted approximately 97 percent of the trees on plot 66. The least abundant of these was water tupelo (tupelo). This species fell primarily in the intermediate and overtopped crown classes so that most of the tupelo trees on the plot were barely visible from above. For this reason, only bald-cypress, willow, and green ash were considered in the classifications performed on plot 66.

Plot 70 contained mostly American sycamore (*Platanus occidentalis* L.), eastern cottonwood (*Populus deltoides* Bartr. ex. Marsh.), and boxelder (*Acer negundo* L.). These three species comprised approximately 92 percent of the trees on the plot. Five other species – willow, bald-cypress, water oak (*Quercus nigra* L.), sugarberry (*Celtis laevigata* Willd.), and red maple (*Acer rubrum* L.) – were present in small numbers.

Within plot 65 the species composition was primarily willow, bald-cypress, and sycamore. The fact that each of these species was contained in one of the other plots helped determine the ground truth strategy for this plot, which was to avoid delineating individual trees on photographs while in the field, as was done with the other plots. Instead, aerial photos alone were used to determine tree species prior to classification. No rigorous accuracy assessment of the air-photo interpretation in this study was conducted. However, experience relating tree-crown color and texture on the large-scale CIR photos to trees in the field on plots 66 and 70 indicated that a high degree of accuracy could be expected. At any rate, air-photo interpretation was taken as ground truth for plot 65. According to data from the 1984 Forest Service inventory of the Basin, the six species examined here account for 51.6 percent of the commercially important trees in the Basin*.

Image Acquisition

Two video-missions were flown, one each during May and November of 1988, to obtain multitemporal imagery of the plots. The timing of the missions was designed to exploit differences in vegetative reflectance between leaf-out and senescence. The aircraft was a small single-engine Cessna with a large camera bay to facilitate the use of two cameras, the video camera and a 70-mm Hasselblad camera. The video camera used was the Xybion Electronic Systems MSC02 (Figure 3) which contained a 6.6-mm by 8.8-mm CCD image sensor with 384 (horizontal) by 245 (vertical) photosites and a rotating filter wheel that allowed a set of sequential images to be obtained in different spectral bands every 0.0167 seconds (60 rps). With this camera, each filter has its own aperture which may be adjusted prior to flight based on expected target responses. A drawback, however, is the difficulty in adjusting the lens aperture during flight when changes in image brightnesses are caused by different filter responses. Also, registration of a sequence of images was necessary because the rotating filter wheel caused images from different bands to be sensed in field sequence, i.e., every other line on the detector is scanned in 1/60 of a second, and spectral filters pass in front of the detector at this rate. During flight, images were recorded on VHS cassettes.

The first mission was flown in May to take advantage of the varying spectral reflectances of the early growing foliage of trees during spring. The second mission was flown in November to monitor the change of leaf color on deciduous trees and the leaf-off condition. Multitemporal images were used together to take advantage of patterns of reflectance variation among species.

The image altitude used in this study was 305 m. With the focal length of the video camera lens set at 25 mm, the

*Computed from data obtained from the Southern Forest Experiment Station for plots located within the Basin.

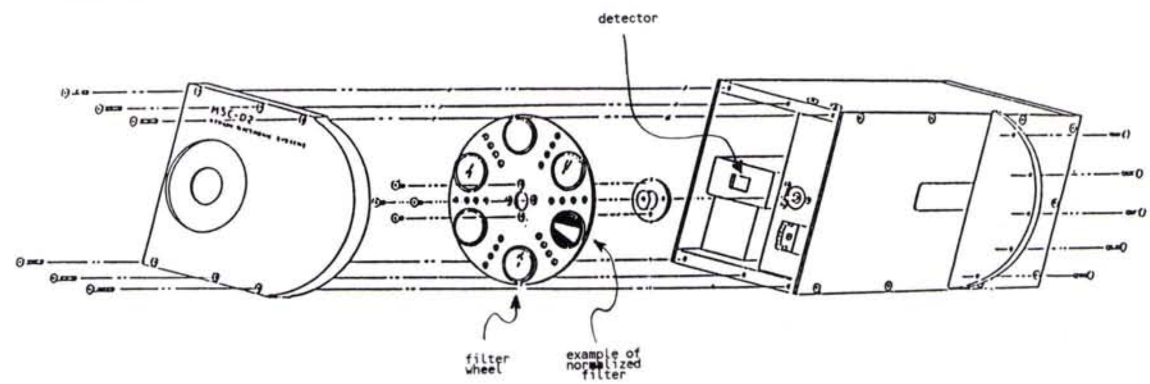

Figure. 3. Exploded view of Xybion MSC02 multispectral camera.

ground-level dimension of image pixels was 0.329 m. This assumes a constant ground elevation of 6.1 m as determined by elevation information on U. S. Geological Survey 15-minute series topographic maps of the area. Ground coverage per image was 0.83 Hectares. The crowns of the trees visible on the imagery ranged from approximately 1.5 m to 7.6 m in diameter. Thus, each tree crown was at least four to five pixels across. During each video mission, aerial photographs were taken with the 70-mm Hasselblad camera and Aerochrome film. An enlarged hardcopy print was prepared for each plot and, for plots 66 and 70, taken to the field for location of individual trees.

Reflectances in the following spectral bands were recorded in this study: (1) 550 nm (visible green) cw, (2) 800 nm (NIR) cw, and (3) 1000 nm (NIR) cw. Henceforth, these will be referred to as bands 1 through 3, respectively. Each band was from approximately 50 to 75 nm in width at 50 percent of peak transmission. The band-pass filters required normalization prior to flight. Normalization consisted of masking each of the filters at some angle based on the characteristics of the filter, the camera sensor, and the reflectance of the prospective target. Masking involved applying opaque tape to the round filters (leaving open a pie-piece formation expanding radially outward toward the edge of the wheel) to leave open only the portion needed for the specified aperture. This is done partially to compensate for the difference in linear velocity between the outer and inner portions of the filters on the rotating wheel. This procedure is intended also to facilitate a similar sensor response for each filter.

Image Processing

Digitization and sequential image registration were performed on an IBM computer with an INTEL 80286 processor and an 80287 math coprocessor. The Xybion Electronic Systems XICAS3 image processing system was used for this purpose because its image display hardware easily handled the digitization of sequential images acquired by the Xybion camera. Multitemporal merging and classification were performed on a similar computer with the Decision Images, Inc. image processing system called RESOURCE[†].

Registration was required because the images in a sequence were not taken simultaneously and therefore were not taken from exactly the same location. A full sequence of three images was recorded over a time span of 0.0167 seconds. This translated to a distance of approximately four pixels (1.32 m) between images at an assumed average airspeed of 80 knots at 305 m altitude. Images from bands 1 and 3 were registered (overlaid) with those of band 2, causing a loss of four pixels on the bottom of band 1 images and on the top of band 3 images. Therefore, when images from the three bands were overlaid, the coverage was slightly less than that of one image (0.80 Hectares).

Slight differences in altitude created scale differences between the May and November 1988 video missions. In addition, the apparent direction of the aircraft at the time it passed a plot was not identical on the different dates due in part to different wind conditions. For these reasons the RESOURCE image warping function was used to merge (i.e., overlay by means of a mathematical four-point transformation) images from the two dates. Time was required also to align the warped image with its temporal counterpart after the calculations were made. If the registration was inadequate, the warping points would have to be adjusted and the procedure started over. This trial and error procedure was quite time consuming.

Classification

Supervised computer classification procedures were employed. Training statistics were collected from unshaded areas of individual trees whose species were known. The classification routines chosen for use in this work were the minimum-distance classifier and the maximum-likelihood classifier, both resident in RESOURCE.

Spectral statistics were acquired from four trees, separately located around the image, of each species visible in the plot scenes. This was done in an attempt to cover the range of spectral responses of each species. Accuracy of classification was determined at the tree level rather than the pixel level; i.e., if the image area corresponding to the sunlit portion of a tree crown was classified correctly, that constituted a correct classification. It was understood that the utility of this method is questionable without a human interpreter to delineate tree crowns. However, the advent of an algorithmic delineation procedure would render this method quite useful. Accuracy assessments were not made at the pixel level because delineation of tree crowns would still have been required, and the tree-level results were judged to be more useful. Each tree was considered classified as a certain species if the majority of the unshaded portion of the

[†]Mention of a trade name, a proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture or cooperating institutions and does not imply approval of the product to the exclusion of others that may be available.

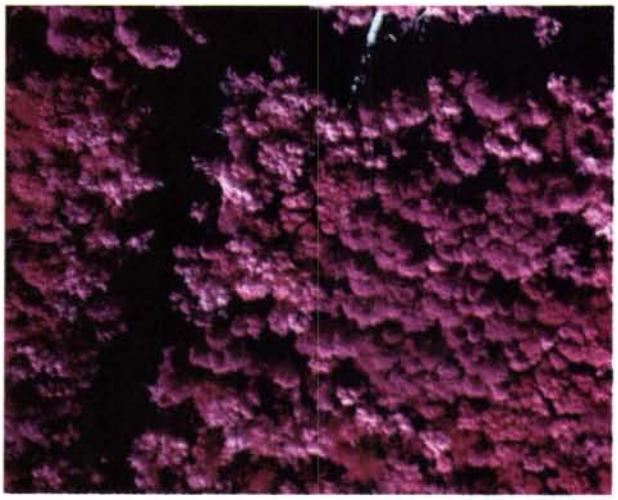

Plate 1. CIR photograph of plot 66.

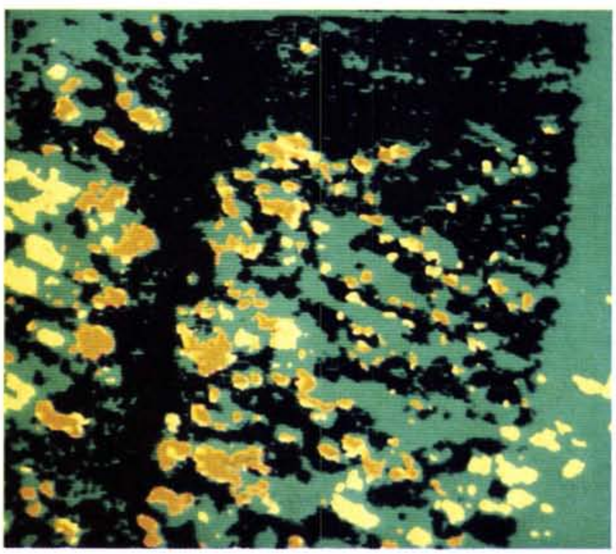

Plate 2. Video image of plot 66 after classification. Dark yellow is willow, light yellow is cypress, green is green ash, and black is water or open ground.

tree crown came under the classification color assigned to that species during the training process. The classification was performed and the results were compared, excluding trees on image edges, with an overlay image on which the trees in question were annotated according to species, based on field checks from plots 66 and 70, and air-photo interpretation of plot 65.

Results

From the literature (Maclean *et al.*, 1985), maximum-likelihood classification was expected to yield results superior to those of the minimum-distance classifier. However, in this study very similar accuracies were obtained with the minimum-distance classifier. The maximum-likelihood classifier required approximately 12 times the calculation time of the minimum-distance classifier. With minimum-distance classification, and only the three bands from the May imagery, classification accuracy was 63 percent. With only bands 1 and 2 from the November imagery, classification accuracy was 58 percent. Inclusion of band 3 from the November imagery did not improve accuracy. The minimum-distance classifier, with bands 1 and 2 from the May and November imagery and band 3 from the May imagery, achieved the highest accuracy. Approximately 78 percent weighted accuracy** was achieved on plot 66, not including correct classifications of training samples. Thus, the use of temporal features improved the accuracy of classification. Plate 1 is a CIR photograph of plot 66, and Plate 2 is a video image of the plot after classification. On plots 70 and 65, the trees were classified with accuracies of 64 percent and 69 percent, respectively. Tables 1 to 3 are contingency tables of the classification data for plots 66, 70, and 65, respectively.

Because the species on plot 65 were contained on the other plots, an attempt was made to verify the results by classifying plot 65 based on training data obtained from plots 66 and 70. This procedure was expected to be relatively unsuccessful because the illumination of the scenes was not necessarily the same. Nevertheless, direct application of training statistics from plots 66 and 70 to the classification of plot 65 resulted in an unbiased weighted accuracy of 70 percent (Table 4).

Based on chi-square analyses of classification results, a

**Weighted, or overall, accuracy is the accuracy per tree-crown; e.g. (plot 66),

$$78\% = \frac{(91 - 4)(78\%) + (59 - 4)(71\%) + (29 - 4)(92\%)}{(91 - 4) + (59 - 4) + (29 - 4)}$$

TABLE 1. CONTINGENCY TABLE FOR CLASSIFICATION OF PLOT 66*.

Known Tree Type	Number of Trees	Percent Correct	Number of Trees Classed into Category		
			Cypress	Willow	Ash
Cypress	91	79 (78)	72 (68)	13	6
Willow	59	73 (71)	16	43 (39)	0
Ash	29	93 (92)	0	2	27 (23)
Percent correct of trees classed in this category			82 (81)	74 (72)	82 (79)

* Numbers in parentheses exclude trees used to generate training statistics.

TABLE 2. CONTINGENCY TABLE FOR CLASSIFICATION OF PLOT 70*.

Known Tree Type	Number of Trees	Percent Correct	Number of Trees Classed into Category		
			Sycamore	Boxelder	Cottonwood
Sycamore	36	75 (72)	27 (23)	0	9
Boxelder	6	67 (0)	1	4 (0)	1
Cottonwood	15	67 (55)	5	0	10 (6)
Percent correct of trees classed in this category			82 (79)	100 (−)	50 (38)

* Numbers in parentheses exclude trees used to generate training statistics.

TABLE 3. CONTINGENCY TABLE FOR CLASSIFICATION OF PLOT 65*.

Known Tree Type	Number of Trees	Percent Correct	Number of Trees Classed into Category		
			Sycamore	Willow	Cypress
Sycamore	12	75 (63)	9 (5)	2	1
Willow	84	69 (68)	6	58 (54)	20
Cypress	41	76 (73)	2	8	31 (27)
Percent correct of trees classed in this category			53 (38)	85 (84)	60 (56)

* Numbers in parentheses exclude trees used to generate training statistics.

TABLE 4. CONTINGENCY TABLE FOR CLASSIFICATION OF PLOT 65 BASED ON TRAINING DATA FROM PLOTS 66 AND 70.

Known Tree Type	Number of Trees	Percent Correct	Number of Trees Classed into Category		
			Sycamore	Willow	Cypress
Sycamore	12	83	10	1	1
Willow	84	68	16	57	11
Cypress	41	63	4	11	26
Percent correct of trees classed in this category			33	83	68

tree's actual species was significantly related (at the 0.05 level) to its species classification for each of the classifications in Tables 1 to 4. An odds ratio analysis determined that, for all the trees considered in the plots where a particular type was present, the odds were 11.7:1 that each would be correctly classified as either cypress or non-cypress, 11.7:1 for willow, 260.7:1 for ash, 0:1 for boxelder, 2.9:1 for cottonwood, and 21.0:1 for sycamore.

Conclusions

Due chiefly to time considerations, the minimum-distance classifier was superior to the maximum-likelihood classifier for statistical differentiation. The most accurate classification procedure in the study consisted of bands 1, 2, and 3 from May 1988; bands 1 and 2 from November 1988; and minimum-distance classification. For the six species considered – namely, willow, cypress, green ash, sycamore, cottonwood, and boxelder – the average classification accuracy for all plots with this method was 70 percent.

The results of this work showed that bands 1, 2, and 3 were useful for differentiating tree species in the Atchafalaya Basin. The use of temporal features improved classification accuracies, but the image merging required for their use was tedious and slow. Although further work is necessary to confirm and improve upon these results, the use of computer image processing and classification of multispectral aerial videography shows promise for use in forest inventories.

Discussion

Considerations which could improve classification accuracy include accounting for view angle and bi-directional effects and vignetting. Such an improvement would bring about more even intensity levels across the image. Another possible improvement, based on the literature (Hazard, 1987; Olson and Good, 1962), could result from measuring red reflectance (600 to 700 nm) during the senescent period. If accuracy levels were acceptable for this type of inventory, its rapidity and relatively low cost would make it attractive as an extension of the current plot-based CFI system. Updates of a large number of plots could be produced in between the more intensive ground inventories.

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