Distinguishing Weed from Crop Plants Using Video Remote Sensing

A. J. Richardson
R. M. Menges
P. R. Nixon
USDA Agricultural Research Service, Weslaco, TX 78596

ABSTRACT: Aerial video images were analyzed digitally using remote sensing image processing techniques to distinguish johnsongrass (*Sorghum halepense* [L.] Pers.) and pigweed (*Amaranthus palmeri* S. Wats) plots from sorghum (*Sorghum bicolor* [L.] Moench), cotton (*Gossypium hirsutum* L.), and cantaloupe (*Cucumis melo* L.) plots. Aerial video imagery were collected at 900 m over a completely randomized block designed field experiment (six treatments and four replications) on 31 May and 24 July 1983. Video imagery were recorded with blue, yellow-green, red, and infrared narrowband spectral filters over the lenses of four black-and-white video cameras. Supervised maximum likelihood classification procedures were used to determine the accuracy of estimating the weed and crop plot areas. Multidate estimation of weed plot areas averaged within 9 percent of the designed experimental area. Single date estimation of weed plot areas averaged within 26 and 32 percent of the designed experimental plot areas. These results indicate that digital video images, using off-the-shelf remote sensing image processing techniques, can distinguish between homogenous weed and crop experimental plots. Thus, it seems feasible that video remote sensing may provide accurate near-real-time information on weed infestation amounts that are mixed within actual crop plant stands.

INTRODUCTION

FARM MANAGERS AND CONSULTANTS need techniques that can provide near-real-time information for making accurate and timely agricultural management decisions. Video remote sensing has been proposed as a technique to provide near-real-time information about plant and soil conditions (Manzer and Cooper, 1982; Escobar *et al.*, 1983; White 1983; Nixon *et al.*, 1983, Nixon *et al.*, 1984). One advantage of video remote sensing is its intrinsic compatibility to computer image processing systems. Advanced remote sensing image processing procedures are rapidly becoming more available to the farm manager and consultant because of the increase in inexpensive home and office computer technology and communication networks. Video imagery can be digitized and entered into image processor computer systems for real time analysis.

The objective of this research was to distinguish weeds from crops, grown in a designed experiment with known plot areas, by classifying video imagery with current available image processing classifier functions. Because the use of video in remote sensing is new, the goal was to use homogeneous experimental plots to test the feasibility of using digital video data to distinguish between crop and weed plants and to estimate their plot areas. If a test such as this is successful, then actual weed infestations mixed within real crop stands should be studied. Such studies can lead toward an enhanced capability to detect and make area estimates of weeds in important agricultural row crops.

MATERIALS AND METHODS

Video imagery was acquired for a completely randomized block designed field experiment (six treatments and four replications) near Weslaco, Texas that had crop, weed plant species, and bare soil plots on 31 May and 24 July 1983. The imagery for these dates was collected near noon on moderately sunny days from an altitude of 900 m (3000 ft) using a single-engine 182 Cessna aircraft. The crop plant species in the experimental plots were cotton (*Gossypium hirsutum* L.), cantaloupe (*Cucumis melo* L.), sorghum (*Sorghum bicolor* [L.] Moench); and the weed plots were johnsongrass (*Sorghum halepense* [L.] Pers.) and pigweed (*Amaranthus palmeri* S. Wats). Bare soil plots were also included as part of the experimental design.

Dimensions of the 24 experimental plots (6 groups × 4 replications) were 23.3 by 30 feet. Cotton and sorghum occupied 23.3 by 26 feet inside their respective plots. Approximately 1,633 video image pixels were digitized within each plot. Thus, resolution was about 0.428 ft^2 per digitized video image pixel as stored in the image processor image data base on disc.

The video system consisted of four black-and-

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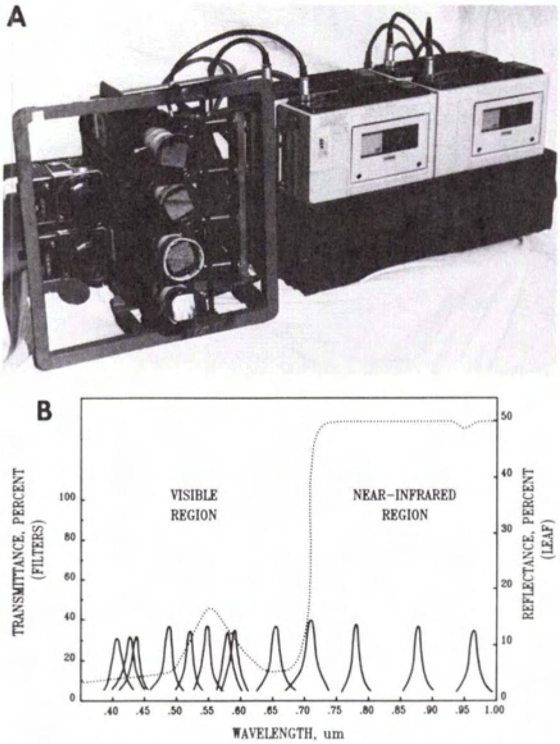

FIG. 1. (A) Video recording system consisting of four black-and-white Sony AVC-3450 video cameras with corresponding Sony SLO-340 Betamax I video cassette player/recorders (VCR). Two Hasselblad cameras are part of the overall imaging system. (B) Transmittance band width spectral characteristics of Specrocoat monopass filters that were used with the video recording system. The dotted line illustrates typical visible and near infrared leaf light reflectance over the 0.4 to 1.1 um waveband.

white Sony AVC-3450 video cameras (Figure 1A)[1], each with a Sony SLO-340 Betamax I video cassette player/recorder (VCR)[1]. One of four cameras was modified with an RCA Ultricon (TM) 4875/U camera tube[2] to have a sensitivity in the 0.4- to 1.1-μm waveband. The other three cameras had a sensitivity in the 0.4- to 0.7-μm waveband. Visible and near-infrared narrowband filters were placed over the camera lenses to allow the video camera system to record any selected light segment within the visible/near-infrared region of the electromagnetic spectrum.

Figure 1B depicts the spectral light transmittance characteristics and band width of the Spectrocoat monopass narrowband filters[3] that can be used with the cameras. The dotted line illustrates typical single leaf visible and near infrared leaf light reflectance over the 0.4- to 1.1-μm waveband. Video images were obtained using a blue (0.42 to 0.43 μm), yellow-green (0.52 to 0.55 μm), red (0.64 to 0.67 μm), and reflective infrared (0.85 to 0.89 μm) filters. Camera aperatures were *f*1.8, *f*2.8, *f*1.8, and *f*8.0, respectively.

Narrowband filtered video images of the experimental plots were entered into an I2S Model 70/F12 Image Processor[4] using a Model SLO-383 Betamax VCR[1]. The VCR was interfaced to the Image Processor video digitizer through an Edutron time base corrector, Model CCD2H-3[5]. The video recording of the experimental plots, for each of the four narrowband filter images, was digitized and stored on an HP-1000, Model 65, series F computer[6]. The image processor control point and warp functions were used to spatially register the four digitized black-white narrowband video images of the experimental plots.

False color video composites were generated for display on a 19-inch diagonal color monitor by using the red, green, and blue color channels of the image processor using triple-wise combinations of the four digitized black-white images.

The I^{2}S Image Processor (TRAIN) function was used to select digitized video data from each plot for each of the four filters on each date. These data were used with the (PREPARE) function to compute the mean and covariance matrices for each of the six training categories for each date. The digital count video mean for each individual plot, for each of the four filters, for each date, was also computed by the (PREPARE) function. The mean and covariance matrices for each of the training categories were used with the image processor I^{2}S CPU'CLASSIFY function to classify both the 31 May and 24 July 1983 video images of the experimental plot. The I^{2}S CPU'CLASSIFY function is available technology that is based on the maximum likelihood ratio theory that identifies the training site statistics that a candidate set of digital values most resembles.The function classified a complete 512 by 512 pixel image in this manner. If a candidate measurement does not resemble any category, then it is assigned to a threshold category. The threshold was set at the 1 percent probability level for this study.

An HP-1000 computer program was developed to compute percent recognition accuracy and percent area estimation accuracy from the classified images. A ground truth experimental plot mask was used as the standard to compute recognition accuracy and area estimations. Classification results were computed for both of the single dates and for both dates

[1] Sony Communications Product Company, New Jersey.

[2] RCA Electro Optics and Devices, Lancaster, Pennsylvania.

[3] Optics Technology Inc., Palo Alto, California

[4] International Imaging Systems, Inc., Milpitas, California

[5] Edutron, Inc., Norcross, Georgia

[6] Hewlett Packard Company, Cupertino, California

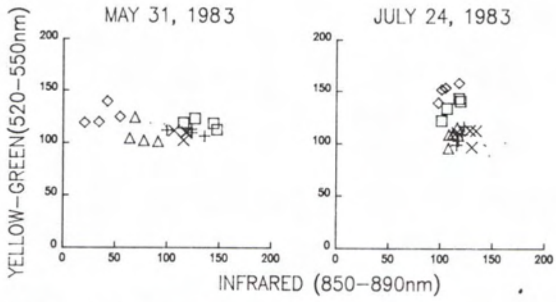

FIG. 2. Two dimensional scatter diagram using near infrared and yellow-green mean spectral data of the four plot replications of cotton (dot), sorghum (triangle), johnsongrass (crosses), pigweed (plus signs), cantaloupe (boxes), and bare soil (diamonds).

taken together (Richardson *et al.*, 1972). Recognition and area estimation accuracy are independent measures of the classification results. That is, it is possible to have good area estimation accuracy but low recognition accuracy, and vice-versa.

The mean video data for each plot from the yellow-green and infrared camera filters were plotted as two-dimensional scatter diagrams. The group clusters formed in these scatter diagrams provide insight into classification results. The mean and standard deviation for each group were also obtained.

RESULTS AND DISCUSSION

Mean digitized plot video data (31 May and 24 July 1983), for all six experimental groups and four replications, in the yellow-green and infrared bands were plotted as a scatter diagram (Figure 2). These two bands closely simulate Landsat MSS bands 5 and 7 on which the Richardson and Wiegand (1977) bare soil line concept is based. They found that increasing plant maturity is directly proportional to the plant cluster distance from the bare soil cluster. Overall group mean and standard deviations are given in Table 1. The relatively small standard deviations indicate that the plots were spectrally homogeneous. On the May date cotton (dots) and sorghum (triangles) were closer to the bare soil cluster (diamonds) than johnsongrass (crosses) and pigweed (plus). Thus, early in the season weeds appear more vigorous than the still maturing cotton and sorghum. Cantaloupe (boxes), in May, was furthest from the bare soil because this category was near to peak maturity. The infrared band provides greatest separability among all categories for May; probably because crop plants were still maturing.

By July (Figure 2) cantaloupe (boxes) had lost many leaves at harvest stage and its means were closest to the bare soil cluster (diamonds). The cotton (dot) cluster was furthest from bare soil in July since it was near peak maturity. The weeds (crosses and plus) seemed to have about the same vigor in July as in May. The yellow-green band seemed to contribute more to separation among all categories in July, probably because the crops were near maturity. The video data presented here are not calibrated for reflectance, but are standardized to the extent that the same lens aperture stops were used on the two dates. As video technology for remote sensing matures, and better equipment is employed, it is likely that narrowband data will be calibrated for reflectance.

The classification accuracy results of all six groups for May and July are in Tables 2, 3, and 4. An experimental plot image mask (Plate 1A) was used to compute the commission—ommission classification matrices given in these Tables. The mask limited the classification assessment to the inside portion of

TABLE 1. DIGITAL VIDEO MEAN AND STANDARD DEVIATION OF SIX EXPERIMENTAL GROUPS FOR THE BLUE (BLU), YELLOW-GREEN (YG), RED (RED), AND INFRARED (RIR) CAMERA FILTERS ARE GIVEN FOR THE MAY AND JULY DATES. THE MEANS ARE THE TOP LINE AND STANDARD DEVIATIONS ARE THE BOTTOM LINE WITHIN EACH GROUP. THERE ARE APPROXIMATELY 10,000 PIXELS USED TO COMPUTE EACH MEAN AND STANDARD DEVIATION

Experimental Group	31 May 1983				24 July 1983			
	BLU	YG	RED	RIR	BLU	YG	RED	RIR
Soil	102	126	103	41	96	151	139	103
	6	8	9	1	9	8	9	7
Johnsgrass	75	108	60	114	57	106	115	125
	2	5	3	6	6	8	8	9
Pigweed	74	102	55	119	57	107	117	118
	2	5	2	1	4	6	7	4
Cotton	80	117	63	94	54	97	116	152
	4	3	6	11	5	6	7	8
Sorghum	76	104	60	76	59	106	107	111
	3	5	4	12	7	8	8	5
Cantaloupe	78	118	59	132	80	135	131	112
	2	5	4	2	6	8	6	7

TABLE 2. PERCENT COMMISSION—OMISSION CLASSIFICATION MATRIX FOR 31 MAY 1983, FOR DISTINGUISHING WEED AND CROP EXPERIMENTAL PLOT VIDEO DATA. TOTAL PIXELS WERE 39,192. CATEGORIES USED WERE SOIL, JOHNSONGRASS (JG), PIGWEED (PIG), COTTON (COT), SORGHUM (SORG), AND CANTALOUPE (CANT)

Commission Error	Plot Design Total %	Omission Error							Correct Classification %
		SOIL %	JG %	PIG %	COT %	SORG %	CANT %	THR %	
SOIL	16.4	16.0	0.0	0.0	0.3	0.0	0.0	0.1	97.6
JG	16.7	0.2	8.9	2.0	3.1	1.1	1.4	0.0	53.3
PIG	16.2	0.0	0.8	9.4	2.1	0.2	3.5	0.0	58.0
COT	17.3	0.9	0.0	0.2	15.2	0.5	0.3	0.2	87.9
SORG	16.7	1.2	0.1	0.0	1.2	14.1	0.0	0.1	84.4
CANT	16.7	0.1	0.1	0.1	4.1	0.2	11.7	0.4	70.1
overall	100.0	18.4	9.9	11.7	26.2	16.1	16.9	0.8	75.3
area estimation	(%)	12	41	28	51	4	1	—	32

TABLE 3. SAME AS TABLE 2 EXCEPT FOR 24 JULY 1983

Commission Error	Plot Design Total %	Omission Error							Correct Classification %
		SOIL %	JG %	PIG %	COT %	SORG %	CANT %	THR %	
SOIL	16.4	14.4	0.0	0.1	0.1	0.5	1.3	0.0	87.8
JG	16.7	0.0	11.3	1.1	1.1	2.8	0.4	0.0	67.7
PIG	16.2	0.2	4.1	6.8	0.3	4.4	0.3	0.1	41.9
COT	17.3	0.3	1.3	0.2	13.2	0.7	0.6	1.0	76.3
SORG	16.7	0.4	0.2	0.6	0.1	12.7	2.3	0.4	76.0
CANT	16.7	1.1	0.2	0.2	0.0	0.4	14.8	0.0	88.6
overall	100.0	16.4	17.1	9.0	14.8	21.5	19.7	1.5	73.2
area estimation	(%)	0	2	44	15	29	18	—	26

TABLE 4. SAME AS TABLE 2 EXCEPT FOR COMBINED 31 MAY AND 24 JULY 1983

Commission Error	Plot Design Total %	Omission Error							Correct Classification %
		SOIL %	JG %	PIG %	COT %	SORG %	CANT %	THR %	
SOIL	16.4	15.8	0.0	0.0	0.1	0.3	0.2	0.0	96.5
JG	16.7	0.2	13.3	1.7	0.6	0.9	0.0	0.0	79.6
PIG	16.2	0.1	2.4	11.9	0.3	0.4	1.1	0.0	73.6
COT	17.3	0.4	0.3	0.2	15.2	1.1	0.1	0.0	87.5
SORG	16.7	0.5	0.2	0.0	0.3	15.5	0.2	0.0	92.6
CANT	16.7	0.2	0.0	0.2	0.0	0.3	16.0	0.0	95.4
overall	100.0	17.2	16.2	14.0	16.5	18.5	17.6	0.0	87.6
area estimation	(%)	5	3	14	5	11	5	—	9

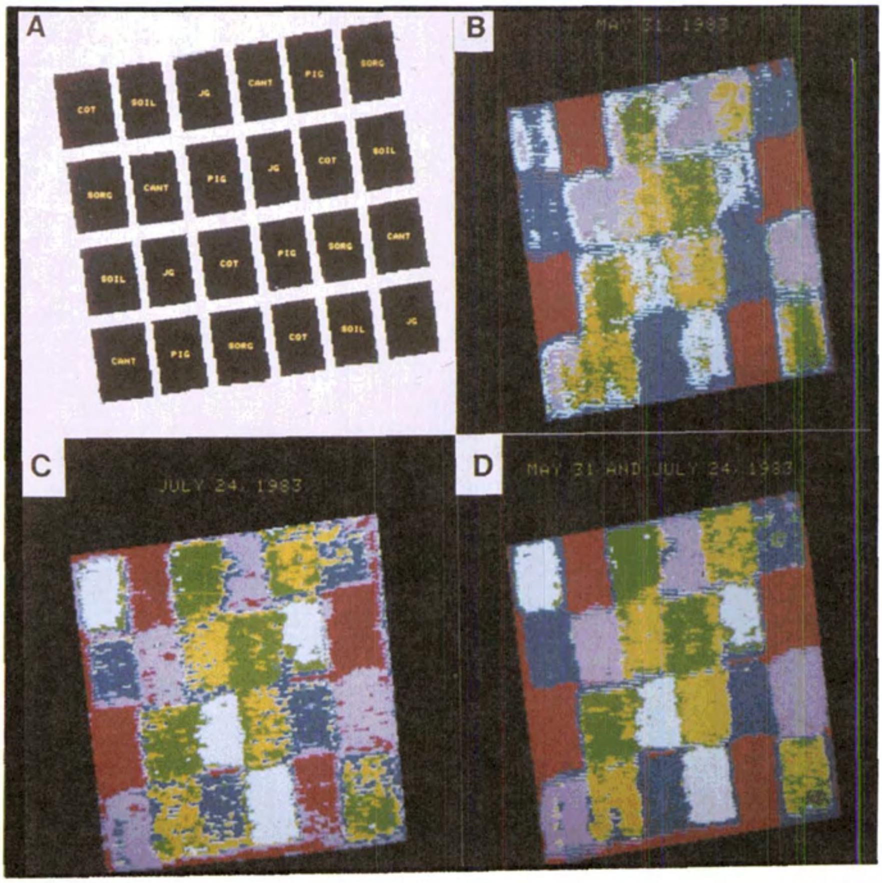

PLATE 1. Experimental plot mask with six treatments and four replications. Treatments are cotton (COT), sorghum (SORG), johnsongrass (JG), pigweed (PIG), cantaloupe (CANT), and bare soil (BS). (B) Color classification results for May corresponding to the ground truth mask. Color index for classification results are: cotton (white), sorghum (blue) johnsongrass (green), pigweed (yellow), cantaloupe (purple), and bare soil (red). (C) Color classification results for July. (D) Color classification results for May-July.

each experimental plot in order to eliminate classification errors due to edge effects between the plots because of incomplete or overlapping vegetation stands.

Plates 1B, 1C, and 1D are the color classification results of all six groups for May and July corresponding to Tables 2, 3, and 4, respectively. Overall category classifications for both May and July were 75 and 73 percent correct classification, respectively, of the observed number of pixels in a category according to the experimental plot mask. Using both dates together increased accuracy to 88 percent. Overall area estimation accuracy (Tables 2 and 3) for May and July was within 32 and 26 percent, respectively, of the experimental plot areas. Using both dates together increased accuracy to within 9 percent of experimental area (Table 4). Multidate analysis improved recognition and area estimations over single date analysis.

CONCLUSIONS

Remote sensing image processing techniques were used to test the feasibility of using digital aerial video data for distinguishing weed from row crop plants. In general, the area of pigweed or johnsongrass can be estimated within 26 and 32 percent of actual by using single date images such as in May or July and to within 9 percent of actual by using multidate classification techniques based on homogeneous experimental plots. Cumulative multidate estimation results were better than single date results. These procedures indicate that video remote sensing may provide accurate near-real-time information on weed infestation amounts mixed within actual crop plant stands.

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