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16. Summary/Notes

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ABSTRACT

Sugarcane (*Saccharum spp.*) plantation of São Paulo State was classified automatically using IMAGE-100 system and LANDSAT digital data. Ten segments of the size 20 x 10 km were aerially photographed and used as training areas for automatic classification. The study area was covered by four LANDSAT paths, 235, 236, 237 and 238. The percentages of overall correct classification for these paths range from 79.56% for path 238 to 95.59% for path 237.

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1. INTRODUCTION

Remote sensing techniques have been applied to agriculture for three basic objectives: 1) to identify different crops according to their spectral characteristics; 2) to determine the best spectral window(s) for crop differentiation, and 3) to obtain multispectral responses of different crops during their growth cycles and under different soil conditions.

Using remote sensing techniques Large Area Crop Inventory Experiment (LACIE) project contributes the first step toward the development of a global scheme for crop forecasting purposes (MacDonald and Hall, 1978). The possibility of deriving vegetative biomass information from LANDSAT MSS data was tested by Wiegand et al. (1973). In their study they concluded that the percentage of exposed soil and the crop growth stage may play a significant role to the spectral response, and through an analysis of spectral response the optimal time for crop discrimination may be selected. Automatic classification of crops using LANDSAT digital data have been experimented by various researchers (Horton and Heilman, 1973; Dietrich et al. 1975). Bauer and Cipra (1973) reported a classification accuracy of 83% for automatic classification of corn and soybean in Northeast Illinois. Higher automatic classification accuracy has been obtained in Baumgardner and Hunderson's (1973) study, the percentages of correct classification was 96.1. 97.0 and 97.9% for pastureland, wheat and bare soil respectively.

Since 1975 the Instituto de Pesquisas Espaciais (INPE) has carried out a series of experiments using LANDSAT (ex-ERTS) data and colour infrared (CIR) aerial photographs for crop classification and area estimation studies. In a study carried out by Mendonça et al. (1978) the sugarcane visual interpretation accuracy using LANDSAT images was compared to that of the automatic classification of LANDSAT digital data and the percentages of correct classification were 83 and 89% respectively.

This paper presents a methodology for sugarcane inventory study of São Paulo State, Brazil. Sugarcane was automatically classified and its area was estimated using an interative image analyser IMAGE-100.

2. MATERIAL AND METHODS

2.1 - STUDY AREA

The selected study area was the sugarcane concentrating area of São Paulo State. The coordinates are 20°00'S ~ 23°30'S and 46°30'W ~ 51°00'W and covers approximately 162,352 km^2 which is about 65.6% of the geographic area of São Paulo State (Figure 1). This area is covered by four LANDSAT paths, 235, 236, 237 and 238 and were taken as four strata in this study.

2.2 - AIRCRAFT DATA ACQUISITION

Owing to the lack of "ground truth" data, aerial photographs were taken for intensive study areas. The information derived from aerial photographs should be used not only for training sample selections in automatic classification processing but also to evaluate the classification accuracy of the IMAGE-100 system.

Considering the different soil types, culture managements, climate and LANDSAT paths which may cause different spectral responses, ten intensive study segments of the size 10 x 20 km^2 were distributed in the study area to represent all the different physiognomic patterns. The CIR aerial photographs (Kodak Aerochrome nº 2443) were taken during the period of May 27 to June 12, 1978 by a RC-10 camera which was equipped on INPE's aircraft - Bandeirante. The focal lenght is 152mm and the camera has an aperture of 5.6. Filter combination W16+CC50C+ +AV3.3 was used for color correction. The scale of the aerial photos was approximately 1:20,000.

2.3 - LANDSAT DATA ACQUISITION

Due to the problem of cloud cover only two LANDSAT passes - April and July/August were available for these ten segments. The LANDSAT imagery (1:250,000) of channels 5 and 7 and the CCTs were used for analysis. Table 1 shows the data of aircraft mission, the path/ row annotation and the LANDSAT pass for each segment. Segment 3 was eliminated from analysis and no temporal comparison was made for segment 4 owing to the lack of LANDSAT data.

2.4 - TRAINNING SAMPLE SELECTION FOR AUTOMATIC CLASSIFICATION

Aerial photographs were interpreted manually and a thematic map (1:20,000) of sugarcane was derived for each segment. The sugarcane fields, which were also recognizable on LANDSAT imagery, were then delineated. For automatic classification, in order to obtain a 1:1 ratio between the CCT pixel and the picture element of the image monitor of IMAGE-100 system, each segment was enlarged to an approximately scale of 1:100,000. Using auxiliary information from aerial photographs, LANDSAT imagery, thematic map and ground data, several sugarcane fields which represented different sugarcane spectral patterns were selected by an electronic cursor. The spectral information of these training samples was used by the classification algorithm "MAXVER" (Velasco et al. 1978) for sugarcane identification. Other auxiliary classes such as pastureland, bare soil, water body and natural forest were also classified using "MAXVER" to provide a better discrimination of the study class-sugarcane. After classification an "alphanumeric theme print" of the scale 1:20,000 was produced by IMAGE-100 for each segment for classification accuracy study.

2.5 - EVALUATION OF CLASSIFICATION ACCURACY

The transparency of sugarcane thematic map based on aerial photographs was over laid on the alphanumeric theme print of each segment and a point by point comparison was carried out. The number of points was multiplied by an "area transformation factor" - 0.3 ha, and the following percentages were used to indicate the IMAGE-100 classification performance:

$$\text{Error of Commission (EC)} = \frac{AC - ACC}{AT - AR} \times 100$$

$$\text{Correct Classification (CC)} = \frac{ACC}{AR} \times 100$$

$$\text{Error of Omission (EO)} = \frac{AR - ACC}{AR} \times 100 = 100 - CC$$

where

AT = the total area of the segment;

AR = the sugarcane area interpreted from aerial photographs;

AC = the IMAGE-100 classified sugarcane area; and

ACC = the correctly classified sugarcane area.

To calculate the overall correct classification for each LANDSAT pass the weighing factor using sugarcane density in each segment was used:

$$w_i = \frac{AR_i/AT_i}{\sum_{i=1}^{N} AR_i/AT_i}$$

were "i" was the number of each segment.

2.6 - SUGARCANE AREA ESTIMATION FOR THE SÃO PAULO STATE

The training samples used to classify sugarcane of each segment in one path were also applied to classify the whole stratum. Estimates of then four strata were them summed to give sugarcane estimation of the whole study area. This estimate from IMAGE-100 was compared to the estimate provided by the Institute for Agricultural Economy (Instituto de Economia Agrícola - IEA).

3. RESULTS AND DISCUSSION

The weather of June 12, 1978 was not favorable for aircraft mission, therefore, only a half of the planned mission coverage was executed for segments 4, 6 and 7. Also due to the high noise of

CCTs for the pass July/August, segments 1, 7, 8 and 10 did not have the same areal extensions as their correspondent thematic maps derived from aerial photographs. Thus, to make data comparisons possible, any alteration of areal extension on aerial photographs or on LANDSAT of one segment, caused the same modification on its correspondent LANDSAT or on aerial photographs. Segment 8 of path 236 in April was shifted to path 237 in July/August and designated as segment 8'.

The areal extension of each segment, the results of sugarcane area interpreted from aerial photographs and estimated using IMAGE-100 system are presented in Table 2 and 3 for the pass in April and July/August respectively. Stratum 236 has the highest sugarcane density (≈52%), stratum 238 the lowest (≈13%) and strata 237 and 235 are the intermediates. The percentages of correct classification, errors of commission and omission for April are shown in Table 4 and for July/August in Table 5.

Generally speaking the percentages of correct classification for July/August are significantly higher and the errors of commission are lower than that for April. These indicate that July/August is a better season for sugarcane classification using a single LANDSAT pass. The explanation for this improvement is that the target which caused classification confusion using IMAGE-100 system was pastureland, specially the artificial pasturelands which are carefully managed and gave a similar spectral response as of sugarcane. Segments 6, 7 and 8 with the most fertile soil of the study region not only have the highest sugarcane densities but also have a large proportional area been planted with pasture for cattle raising. Thus, in April the highest CC and EC of these two segments are comprehensible.

The dry season of the study area starts from April and ends at the beginning of June. Stratum 238 is located in the transition zone of agricultural area and rangeland region of the State, the pastureland of this stratum showed a decline of vegetation vigor in April due to water stress. Thus, the sugarcane of segment 1 and 2 of this stratum presented the same sympton of pasture. In addition, in the transition region the sugarcane rotation in the field is not as dynamic as the strata which are located in the central part of the State where sugarcane is planted and can be found at different stages of development in the whole year. This agronomic culture practice of sugarcane in segment 1 and 2 in April contributes significantly to the characteristics of the spectral pattern of sugarcane which was very similar to that of the pastureland. The small quantity of sugarcane fields with vigorous vegetation aspects caused high omission error. The same segments showed a significant reduction in error of omission when analysed using the data of the pass July/ August.

The classification results of the segments in stratum 236 in April show the variation of commission error from 31.64% for segment 6 to 54.22% for segment 7 while for stratum 238 varies from 8.31% for segment 1 to 14.91% for segment 2. The soil of stratum 236-"Terra Rossa" - retains more soil moisture which is available for plant growth. Thus, even in dry season the pasture of this stratum grows vigorously and presents confusion for discrimination from sugarcane in April. Using the data of July/August the commission error of sugarcane is reduced significantly.

The situations of the segments in strata 237 and 235 are intermediate comparing with strata 238 and 236. In April the commission and omission errors of these segments were almost equal, indicating the same situation as that commented for the segments in strata 238 and 236. The errors of commission are approximately equal for both passes of segment 10 in stratum 235. This may be explained by the natural physical phenomenon related to sugarcane within a highly dynamic environment. Thus, besides the factor of similarity of spectral responses between pasture and sugarcane, the spatial distribution of sugarcane in segment 10 could introduce significant error of commission even in July/August.

Table 6 shows the relative differences of correct classification for each stratum comparing the results for April and July/August. Strata 238 and 235 show the highest improvement (171.81 and 111.54%). This proves that the study area is under the influence of partureland which has the similar spectral characteristics as sugar--cane. The stratum 237 shows an increment of 58.45%, and the lowest incremet is in the stratum 236 (12.85%). This is because the stratum 236 covers an intensive cultivated region with the best soil type, where the highest sugarcane concentration of the whole State is found. In April and July/August or any other time of the year sugarcane is the predominant crop, thus explaining the smallest increment in correct classification from the data of April to July/August.

Extrapolating the information of training samples of the pass July/August to classify sugarcane of the four strata gives a total estimate of 13,349.84 km^2 which shows an overestimate of + 12.57% when comparing to the data provided by the Institute for Agricultural Economy (Instituto de Economia Agrícola - IEA). No classification accuracy was obtained for the study area, however, an overall correct classification of 87.96% was achieved for the eight segments where comparisons to aerial photographs were possible.

4. CONCLUSIONS

LANDSAT CCTs were used for area estimate of sugarcane plantation of the São Paulo State using IMAGE-100 system. The following significant results were obtained from this study:

a) crop thematic map derived from aerial photographs is efficient for training sample selection and provides precise information to evaluate the results of automatic classification using IMAGE-100 system;

b) soil type, crop density and its spatial distribution, and LANDSAT pass are all important factors which influence the spectral characteristics of the study crop;

c) pastureland of the study area has a similar spectral response as sugarcane as well as its large expansion in the study area are the reason for commission error;

d) the repeatitivity of LANDSAT system permits the increment of classification performance of IMAGE-100 through the selection of the optimal pass which is favorable for crop discrimination purpose; and

e) the study results are encouraging, considering the classification performances of the segments which were used to choose training samples for automatic classification of sugarcane area using LANDSAT CCT and IMAGE-100 system.

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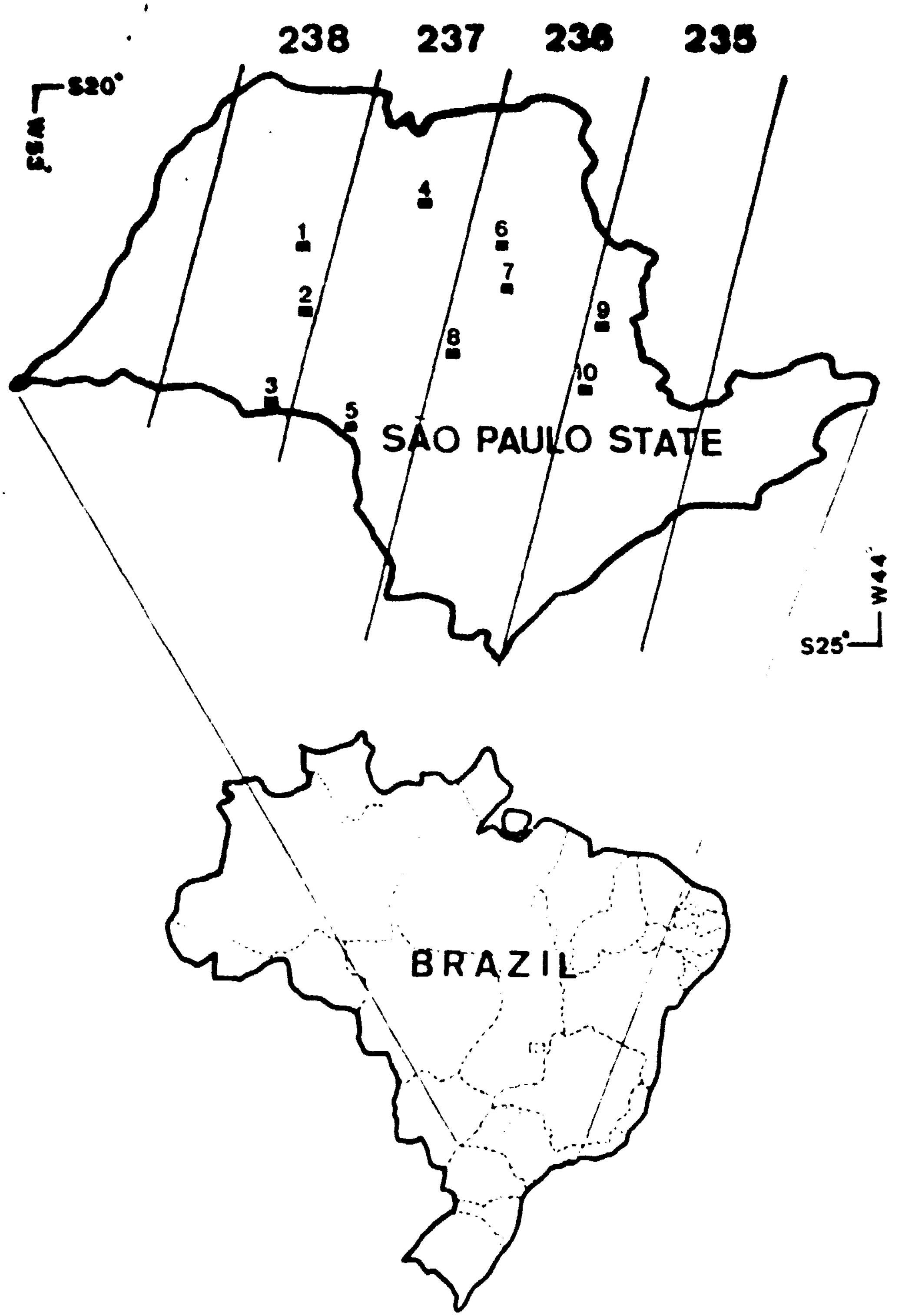

Fig. 1 - Location map of the study area and the ten segments for aerial photographing.

TABLE 1

INFORMATION OF AIRCRAFT AND LANDSAT DATA USED FOR THE STUDY

AIRCRAFT DATA		LANDSAT DATA		
NUMBER OF SEGMENTS	MISSION DATE	PATH/ROW ANNOTATION	PASS	
			APRIL	JULY/AUGUST
1	27/05	238/27	08/04	12/08
2	23/05	238/27	08/04	12/08
3	26/05	238/28	-	-
4	12/06	237/27	07/04	-
5	24/06	237/28	07/04	11/08
6	12/06	236/27	06/04	05/07
7	12/06	236/27	06/04	05/07
8	26/05	236/27	06/04	05/07
9	28/05	235/27	05/04	04/07
10	12/06	235/27	05/04	04/07

TABLE 2

SUGARCANE AREA ESTIMATION USING LANDSAT DATA OF APRIL

STRATUM	SEGMENT NUMBER	AERIAL EXTENSION OF SEGMENT (ha) (AT)	SUGARCANE AREA (ha)		
			AERIAL PHOTOGRAPHS (AR)	LANDSAT DATA (AC)	DENSITY (AR/AT) x 100
238	1	20,013	3,295	2,453	14.46
	2	20,000	2,072	3,181	10.36
237	4	12,023	3,720	4,745	30.94
	5	20,216	4,381	5,534	21.67
236	6	11,468	6,202	6,286	54.08
	7	10,612	5,796	6,739	54.62
	8	19,879	10,030	12,951	50.46
235	9	20,492	5,550	4,195	27.08
	10	20,000	7,432	5,529	37.16

TABLE 3

SUGARCANE AREA ESTIMATION USING LANDSAT DATA OF JULY/AUGUST

STRATUM	SEGMENT NUMBER	AERIAL EXTENSION OF SEGMENT (ha) (AT)	SUGARCANE AREA (ha)		
			AERIAL PHOTOGRAPHS (AR)	LANDSAT DATA (AC)	DENSITY (AR/AT) x 100
238	1	6,617	995	1,213	15.04
	2	20,000	2,072	3,412	10.36
237	5	20,216	4,381	5,604	21.67
	8'	19,350	9,645	10,055	49.84
236	6	11,468	6,202	6,218	54.08
	7	13,480	7,108	6,574	52.73
235	9	20,492	5,550	5,533	27.08
	10	14,600	6,484	7,036	44.41

TABLE 4

POINT-BY-POINT COMPARISON OF SUGARCANE CLASSIFICATION ACCURACY FOR LANDSAT PASS IN APRIL

STRATUM	SEGMENT NUMBER	CORRECT CLASSIFICATION (CC)	ERROR OF OMISSION (EO)	ERROR OF COMMISSION (EC)
238	1	32.36	64.74	8.31
	2	24.52	75.48	14.91
237	4	64.62	35.38	28.19
	5	54.21	45.79	19.95
236	6	74.49	25.51	31.64
	7	71.22	28.78	54.22
	8	79.03	20.97	51.01
235	9	49.08	50.92	9.84
	10	32.97	67.03	24.50

TABLE 5

POINT-BY-POINT COMPARISON OF SUGARCANE CLASSIFICATION ACCURACY FOR LANDSAT PASS IN JULY/AUGUST

STRATUM	SEGMENT NUMBER	CORRECT CLASSIFICATION (CC)	ERROR OF OMISSION (EO)	ERROR OF COMMISSION (EC)
238	1	75.98	24.02	8.13
	2	84.75	15.25	9.24
237	5	94.16	5.84	9.34
	8'	96.21	3.79	8.00
236	6	88.66	11.34	13.65
	7	80.08	19.92	13.84
235	9	92.04	7.96	2.84
	10	79.27	20.73	23.36

TABLE 6

COMPARISONS OF CORRECT CLASSIFICATION OF SUGARCANE FOR LANDSAT PASSES OF APRIL AND JULY/AUGUST

STRATUM	LANDSAT PASS		RELATIVE DIFFERENCE (%)
	APRIL	JULY/AUGUST	
238	29.29	79.56	171.81
237	60.33	95.59	58.45
236	74.81	84.42	12.85
235	39.76	84.11	111.54