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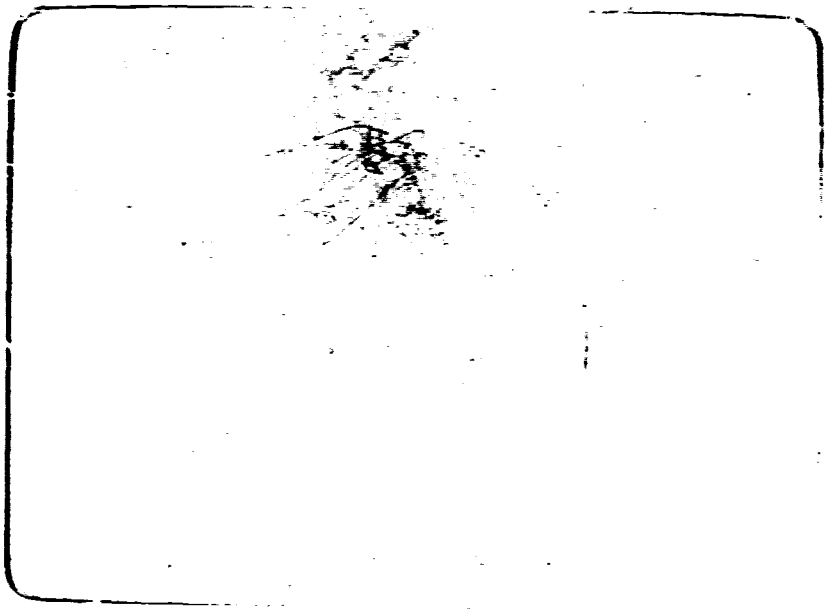

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14. Abstract/Notes

The objective of this paper is to evaluate the utilization of remotely sensed orbital data for forestry inventory. The study area (approximately 491,100 ha) encompasses the municipalities of Ribeirão Preto, Altinópolis, Cravinhos, Serra Azul, Luis Antonio, São Simão, Santa Rita do Passa Quatro and Santa Rosa do Viterbo (São Paulo State). Materials used were: LANDSAT data of channels 5 and 7, scale 1:250,000 and CCTs. Visual interpretation of the imagery showed that for 1977 a total of 37,766.00 ha and for 1979 38,003.75 ha were reforested with Pinus and Eucalyptus within the area under study. The results obtained show that LANDSAT data can be used efficiently in forestry inventory studies.

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EVALUATION OF REFORESTATION USING REMOTE SENSING TECHNIQUES*

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ABSTRACT

The objective of this paper is to evaluate the utilization of remotely sensed orbital data for forestry inventory. The study area (approximately 491,100 ha) encompasses the municipalities of Ribeirão Preto, Altinópolis, Cravinhos, Serra Azul, Luis Antonio, São Simão, Santa Rita do Passa Quatro and Santa Rosa do Viterbo (São Paulo State). Materials used were: LANDSAT data of channels 5 and 7, scale 1:250,000 and CCTs. Visual interpretation of the imagery showed that for 1977 a total of 37,766.00 ha and for 1979 , 38,005,75 ha were reforested with Pinus and Eucalyptus within the area under study. The results obtained show that LANDSAT data can be used efficiently in forestry inventory studies.

1. INTRODUCTION

Reforestation prior to 1966 was considered a non-profit economical activity, when the brazilian government, through an appropriate legislation gave tax incentives opportunities to individuals and/or institutions to make investiments in reforestations. Therefore, the reforestation had a strong impetus after 1966, the area reforested within Brazil increasing from 500,000.00 ha up to 3,800,000.00 ha at 1979.

The accelerated rate of reforestation determined the need for more advanced techniques for monitoring of the implanted reforested resources. The first studies on reforestation areas using LANDSAT data, were performed by Hernandez Filho and Shimabukuro (1978) and Hernandez Filho et alii (1978) at the Northeast portion of São Paulo State.

The objective of this study is to show the feasibility of periodic monitoring of the implanted reforested resources through visual and computer-aided interpretation of LANDSAT data.

2. STUDY AREA

The study area is located in the Northeastern part of São Paulo State, Brazil, including the municipalities of Ribeirão Preto, Altinópolis, Cravinhos, Serra Azul, Luis Antonio, São Simão, Santa Rita do Passa Quatro and Santa Rosa do Viterbo. Occupying an area of 4,911 km², this area located between 21°00'S to 22°20'S and 47°00'W to 48°00'W (Figure 1). This study area was selected because it represents various categories of reforestation population density, age groups and cutting rate of Eucalyptus and Pinus plantations.

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* Presented at the Sixteenth International Symposium on Remote Sensing of Environment, Buenos Aires, Argentina, June 2-9, 1982.

3 MATERIAL AND METHODS

3.1 LANDSAT PRODUCTS

LANDSAT CCT and black and white photographic imagery, path 224 and row 75 from 07/01/1977 and 07/27/1978 are used in this study.

3.2 VISUAL ANALYSIS

For visual analysis of LANDSAT imagery, the channels 5 and 7, black and white, at the scale 1:250,000 in the two acquisition dates were used.

The basic photointerpretation techniques such as multitemporal information in tonality and texture pattern together field information were used to define the preliminary reforestation classes.

The preliminary maps of reforestation unities obtained were compared reforestation plans from the area, to check the mapping of the reforestation.

Subsequently, a final map with the discriminations of the reforestation classes including through a legend and an interpretation key, were obtained.

The mapped unities were quantified with a milimeter grid and the results were presented in hectares, per municipality, in the study area.

3.3 COMPUTER-AIDED ANALYSIS

Computer-aided analysis using Image-100 system was carried out in the study area. CCTs relative to the acquisition date 07/01/77 were used. The computer-aided analysis comprehends three steps: data preparation, signature acquisition and study area classification.

Initially, in the data preparation step, the study area was located on the CCT data. Subsequently, the part of the image that encompasses the study area was enlarged to the scale 1:250,000. The study area was divided in four modules.

The signature acquisition was obtained in two training areas at the scale 1:100,000. The choice of sample areas was carried out based on previous existing reforestation map and visual analysis of the LANDSAT imagery.

The classification of the study area was carried out using the program "MAXVER" (Velasco et al., 1978), and the postprocessing "THEME UNIFORMIZATION". The area was quantified by the program "THEME AREAS".

4. RESULTS AND DISCUSSION

An interpretation key and a legend based on the spectral characteristics of the reforested areas were defined in the visual analysis.

a) Legend

When the reforestation covered completely the soil, the variations due to reforestation spacing, age, species and cutting rate, didn't influence the characterization of the classes. The following classes were defined:

PA - homogeneous Pinus plantation
PB - less homogeneous Pinus plantation
PC - heterogeneous Pinus plantation
EA - homogeneous Eucalyptus plantation
EB - less homogeneous Eucalyptus plantation
EC - heterogeneous Eucalyptus plantation

b) Interpretation Key

The interpretation key presented in Table I, was based on the tonality and photography texture patterns. The tonality was classified in the following classes: CE - dark gray; CE_m - dark gray, with other gray tones; CC_m - light gray, with other gray tones; CM - intermediate gray; CM_m - intermediate gray, with other gray tones and CC - light gray.

The texture was classified in the following classes: L - smooth texture, presented the same gray tone; M - intermediate texture, presented small variation between gray tones; and G - rough texture, presented high variation between gray tones.

The Table II presents the comparison of the results of the reforested areas with Eucalyptus between 1977 and 1979. The increase of reforested areas with Eucalyptus occurred only in the municipalities of Santa Rita do Passa Quatro and Luis Antonio while there was a decrease of reforested area in the municipalitiesSão Simão, Serra Azul and Altinópolis.

The Table III presents the comparison of the results of the reforested areas with Pinus between 1977 and 1979. There was not change of the reforested areas in the municipalities of São Simão, Cravinhos and Altinópolis and in the other municipalities there is no reforestation withPinus.

In the computer-aided analysis the only genus Eucalyptus was classified; the genus Pinus covered too small areas, hence being insufficient for selection of training samples.

For acquisition of spectral signatures of the reforested classes two training areas were chosen:

The Tables IV and V present the mean of spectral responses of the class Eucalyptus, in the four channels and the covariance matrices of this class, respectively, of the first training area.

In the second training area, two subclasses of Eucaliptus were defined: Eucalyptus 1 and Eucalyptus 2 based on the spectral response of the channels 6 and 7 of LANDSAT.

The Table VI presents the mean of the spectral responses of the subclasses Eucalyptus 1 and Eucalyptus 2, in the four channels; and the Table VII and VIII present the covariance matrices of the subclasses Eucalyptus 1 and Eucalyptus 2, respectively of the second training area.

Based on the spectral parameters obtained in the training areas a classification of the study area was carried out. It was found out that an area of 37,364.50 ha was occupied by the class Eucalyptus.

5. CONCLUSIONS

5.1 VISUAL ANALYSIS

The visual analysis showed that it was possible to map the areas of Pinus and Eucalyptus reforestation and to monitor these areas in each municipality.

5.2 COMPUTER-AIDED ANALYSIS

The computer-aided analysis showed that it was possible to classify the areas of Eucalyptus reforestation.

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Table I. Interpretation Key

CLASS	TONALITY		TEXTURE	
	CHANNEL 5	CHANNEL 7	CHANNEL 5	CHANNEL 7
PA	CE	CM/CE	L	L
PB	CE_m	CM_m/CE_m	M	M
PC	CC_m	CC/CM	G	G
EA	CE	CC/CM	L	L
EB	CE_m	CM_m	M	M
EC	CC_m	CM_m	G	G

Table II. Reforested areas with Eucalyptus (period 1977 - 1979), in the study area.

MUNICIPALITY	REFORESTATION AREA WITH EUCALYPTUS IN 1977 (Ha)	REFORESTATION AREA WITH EUCALYPTUS IN 1979 (Ha)	DIFFERENCE OF THE REFORESTATION OF EUCALYPTUS; BETWEEN 1977 AND 1979 (Ha)
STA. RITA DO PASSA QUATRO	8,600.00	9,012.50	(+) 412,50
SÃO SIMÃO	9,092.25	9,086.00	(-) 6,25
LUIZ ANTONIO	2,937.50	3,556.25	(+) 618,75
SERRA AZUL	3,150,00	2,575,00	(-) 575,00
CRAVINHOS	543,75	543,75	-
ALTINÓPOLIS	7,256,25	7,043,75	(-) 212,50
RIBEIRÃO PRETO	4,387,50	4,387,50	-
STA. ROSA DO VITERBO	1,387.50	1,387.50	-
TOTAL	37,354.75	37,592.25	(+) 237,50

Table III. Reforested areas with Pinus (period 1977-1979), in the study area.

MUNICIPALITY	REFORESTATION AREA WITH PINUS IN 1977 (Ha)	REFORESTATION AREA WITH PINUS IN 1979 (Ha)	DIFFERENCE OF THE REFORESTATION WITH PINUS BETWEEN 1977 AND 1979 (Ha)
STA. RITA DO PASSA QUATRO	-	-	-
SÃO SIMÃO	210.00	210.00	-
LUIZ ANTONIO	-	-	-
SERRA AZUL	-	-	-
CRAVINHOS	56.25	56.25	-
ALTINÓPOLIS	145.00	145.00	
RIBEIRÃO PRETO	-	-	-
STA. ROSA DO VITERBO	-	-	-
TOTAL	411.25	411.25	-

Table IV. Mean of the responses of the class Eucalyptus in the four channels of the first training area.

CLASS \ CHANNEL	4	5	6	7
EUCALYPTUS	11,34	12.08	55,23	53.08

Table V. Covariance matrix of the class Eucalyptus of the first training area.

CHANNEL	4	5	6	7
4	2.73	1.52	1.79	2.57
5	1,52	5,32	-0.16	-0,82
6	1,79	-0.16	34.62	31.90
7	2,57	-0,82	31,90	42.85

Table VI. Mean of the spectral responses of the subclasses Eucalyptus 1 and Eucalyptus 2 in the 4 channels of the second training area.

CLASS \ CHANNEL	4	5	6	7
EUCALIPT 1	8.54	9.24	48.66	48.97
EUCALIPT 2	8.83	10.02	34.75	31.78

Table VII. Covariance matrix of the subclass Eucalyptus 1 of the second training area.

CHANNEL	4	5	6	7
4	2.51	0.54	-0.46	0.15
5	0.54	2.23	0.30	0.33
6	-0.46	0.30	21.40	19.40
7	0.15	-0.33	19.40	27.23

Table VIII. Covariance matrix of the subclass Eucalyptus 2 of the second training area.

CHANNEL	4	5	6	7
4	3.03	1.10	-0.30	-0.31
5	1.10	4.22	0.86	0.05
6	-0.30	0.86	19.98	19.81
7	-0.31	0.05	19.81	27.36

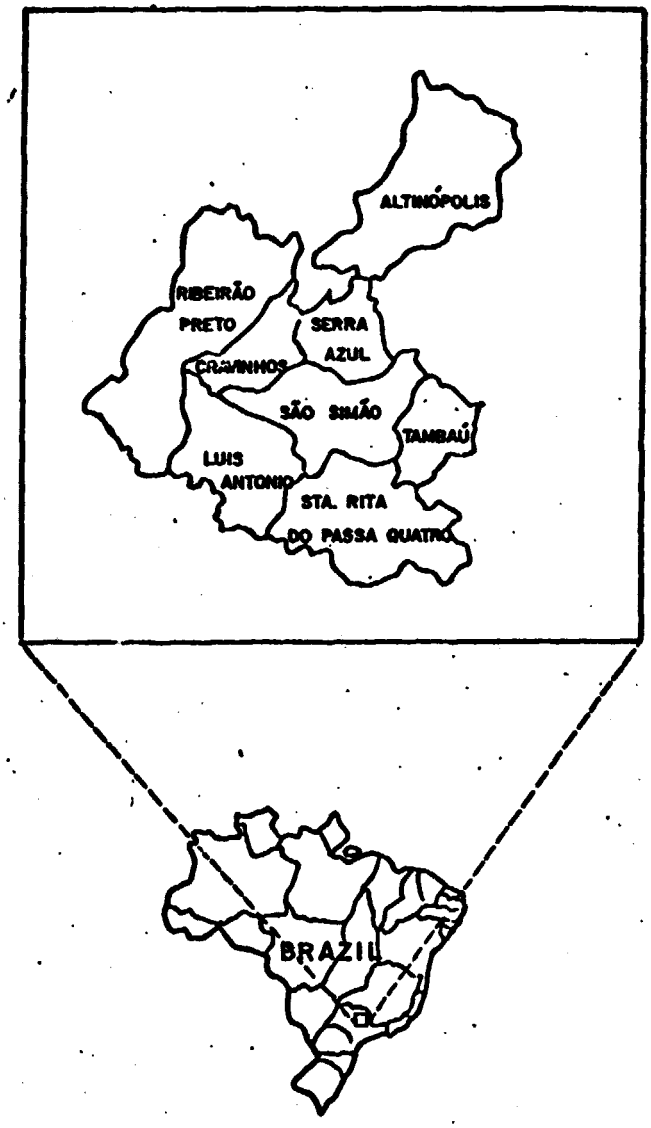

Figure 1. Study area localization.